INNOVATIVE ENGINEERING MODELING TECHNOLOGICAL PROCESS OF URINE COLLECTION IN DOGS

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Abstract. The problem statement is revealed as follows. It is recommended to collect urine in the morning, in a sterile vessel; however, the procedure of this biological material collection in animals is rather challenging in implementation and requires certain effort and practical skills. The purpose is revealed as follows. Meanwhile, urine collection in dogs is rather important in a veterinarian's practice. The test of collected urine allows to check the animal's state of health and to evaluate the obtained results, which is important for research. The methodology is revealed as follows. The research has been done using factual observation and documentation, systemic and morphological analyses. The mathematical model for the technological process has been compiled based on a set theory. The findings (results). A general model for technological process of urine collection has been developed and a description of the model components provided, which allows to view them as a vector of technical support. Originality (novelty). A distinguishing feature of the offered urine collection technological process model is that based on the aggregate of set elements combining processes, means, objects and phenomena of the model, a device has been developed allowing to select optimal sizes depending on the animal breed. The practical value is revealed as follows. The implementation will allow to obtain a convenient comfortable means for urine collection in dogs of different breeds using vessels of different volume.

Keywords: animal, collection, urine, set theory.

Introduction and problem statement

Today's reality has also been a challenge for our animal companions. War atrocities in Ukraine have turned into a disaster the lives of not just millions of Ukrainians but also thousands of dogs and cats. From occupied cities and towns, Ukrainians carried big dogs in their arms, cradled kittens in their bosoms and dragged cages with parrots onto evacuation trains. However, not all animals have been so lucky: some owners died or went missing, and some simply left their pets behind. The animals were extremely exhausted; some could not walk anymore. A fifth of surviving dogs were in a grave state. Therefore, volunteers brought such animals for urgent treatment to public and private veterinary clinics.

However, the possibilities for treatment are a complicated technological process, combining the variables of human, animal and machine [1]. Its course envisages first of all the determination of the animal's physiological state, based on which it is possible to formulate a precise diagnosis, which is also complicated by the need for availability of various technical devices in veterinary clinics taking into account the constitution of each animal [2; 3].

Using more advanced equipment and new instrumental materials will ensure better efficiency of the instruments [4].

The collection procedure requires certain skills from the expert and takes place at a pre-analytical stage [5; 6]. As for blood collection, this process is performed in the veterinary clinic [7]. Feces are collected by the owners into a disposable plastic vessel with limited timeframe for the delivery to the laboratory for testing [8]. Urine collection is performed, if possible, in the morning into a sterile vessel, but this procedure is rather challenging in its implementation and requires certain effort and practical skills [5]. At the same time, urine collection in animals, in particular dogs, is a rather important part of veterinary practice as it allows to check the animal's state of health and to evaluate the obtained results in research [9]. The basic aspects of urine collection include the following:

1. ease of collection,
2. sample quality,
3. contamination prevention,
4. strict adherence to the procedure,
5. level of pain inflicted to the animal,
6. improvement of methods (to reduce stress, pain or distress) [10].

The purpose of this work has been in justification of the requirements for urine collection in dogs based on innovational solutions. To this end, the following objectives were singled out:

- to analyze the process of urine collection, to develop a mathematical model for technical support and principles of its implementation.
- to develop a technical device for urine collection in a sterile vessel depending on its dimensions.

The research has been performed using factual observation and documentation, systemic and morphological analyses. The mathematical model for the technological process has been compiled based on a set theory [11].

Main material presentation

To determine the situation with this or that patient (animal), a veterinary clinic, first of all, conducts comprehensive laboratory testing performed in specially equipped rooms for biomaterial collection [11]. The main materials necessary for collection are blood, urine, feces, etc. [12].

Among the factors influencing the efficiency of our pets' treatment in veterinary clinics not just professionalism of the veterinarian, prescribed medicines and performed procedures are important; we cannot underestimate the medical furniture as well [13].

We need to remember that the quality of collected materials in many cases depends on the "… link in the chain of processes for diagnosing and treating an animal" [14].

The general process analysis is divided in the following phases:

- pre-analytical, during which biomaterial is collected, its chances of storage and ways of delivery to the laboratory are considered;
- analytical, when control is performed over the equipment work and the share of added reagents needed for respective methodology in biomaterial testing;
- post-analytical, when the obtained results are evaluated and discussed, with errors calculated [15-17].

As for the reasonability of animals' urine collection for testing, this procedure is designed to identify diseases, etc. (Fig. 1) [14].

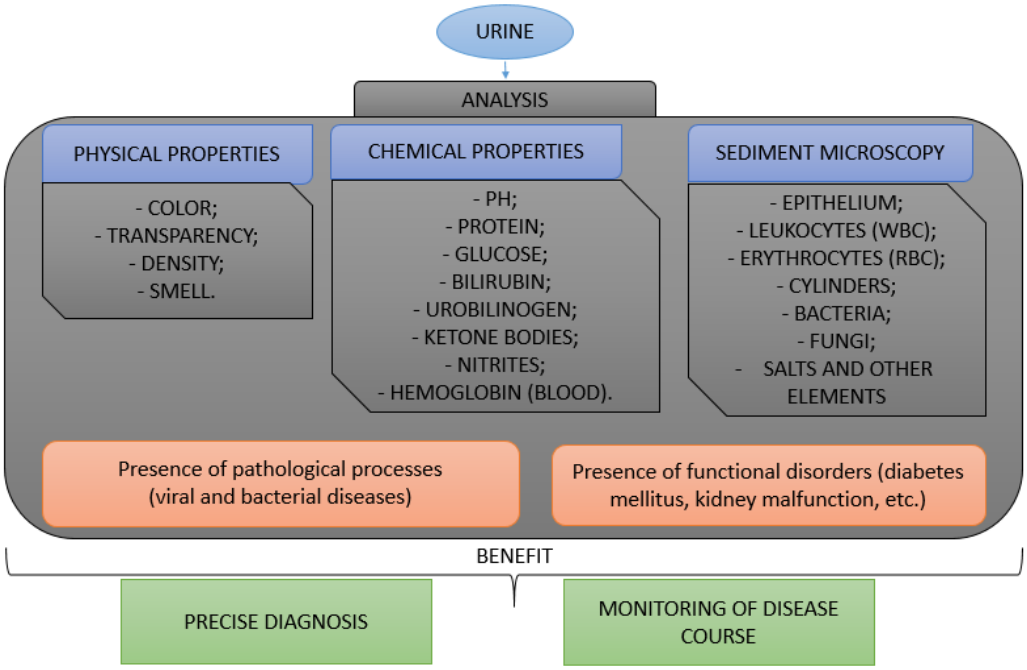

Fig. 1 **Clinical urine analysis**

The foundation of the set theory was formed by a well-known German mathematician Georg Cantor in the second half of the 20th century [18]. The contemporary set theory is a mathematical theory, which serves as a foundation for most chapters of contemporary mathematics [19; 20].

The essence of a set is among the main undefined notions in mathematics. As for the set theory, the term of "set" would belong to primary undefinable notions; in other words, it cannot be defined through other, simpler notions of objects. In this case the explanation is provided on examples appealing to our attention and intuition [21-23].

The objects the given set consists of are called its elements.

- A set is an accumulation of objects combined according to a certain feature.
- A symbol denoting the combination symbol for sets: ∪.

The developed mathematical model will allow to study characteristic properties of the urine collection process and determine the boundaries of its efficient use. On its basis, a structure for a constructive design of a technical device to collect urine regardless of the conditions is developed, taking into account the set theory when determining its efficiency according to the application criteria.

Results and discussion

It is common knowledge that urine collection in animals can be imagined as a process of interaction of components (Fig. 2).

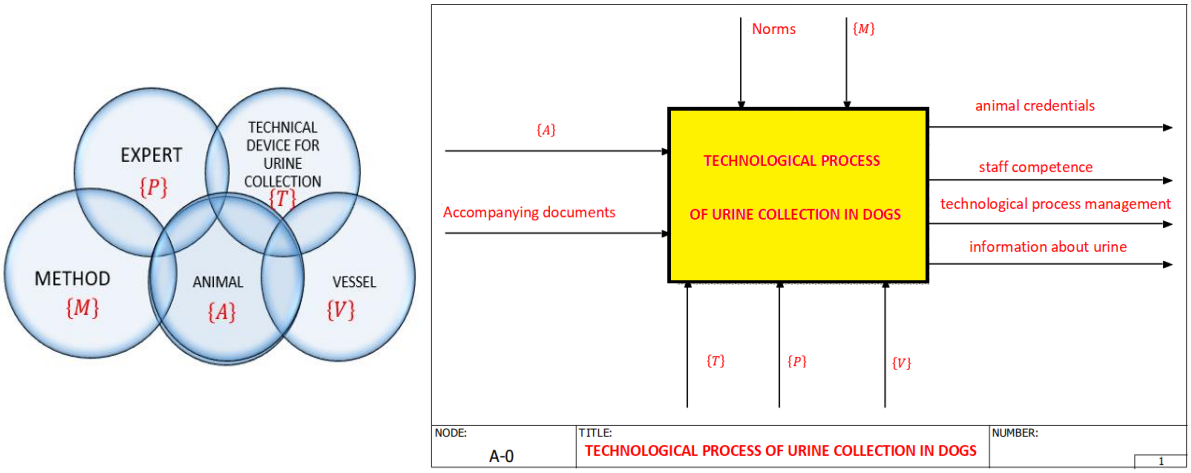

Fig. 2. **Interaction of components during urine collection in animals and the SADT model**

The system of the abovementioned indicators can be described using the following mathematical model from a set theory:

$$\{\Omega\} = \{P\} \cup \{A\} \cup \{M\} \cup \{T\} \cup \{V\} \quad (1)$$

where $\{P\}$ – person;
$\{A\}$ – animal;
$\{M\}$ – means of execution;
$\{T\}$ – technical device;
$\{V\}$ – vessel.

The SADT model was chosen to build the process. The input data of the model are the animal $\{A\}$ and the accompanying documents, the analysis of which should ensure the formation of the account data of the animal, which is the main source of information.

Process management mechanisms include technical means $\{T\}$, personnel $\{P\}$, and inventory $\{V\}$, as these components provide the organizational process.

Regulations and methods of urine collection $\{M\}$ are included in the management of the above process.

The initial information is the registration data of the animal, the competence of the personnel, the management of the technological process, and data about the material.

The current SADT model includes the following elements in the process of implementing the set theory mathematical model system. This system combines various objects, technical means and measures allowing it to function with regard to procedures and regulations for all actions. At the same time, each system element contains its own subsystem with varying evaluations with regard to its constituting objects, components and phenomena.

At that, it is important to take into account the process, namely the conditions and parameters of the execution technique and the type of animal, which are closely related.

Each element depends on its own factors.

{*P*} – person

$$\{P\} = \{AO;VD\} \quad (2)$$

A person collecting biomaterial (urine) can be the animal owner {*AO*} or a veterinary doctor {*VD*}.

Ensuring competence of the mathematical model {*P*} components will allow to design these aspects more precisely at the justification stage. A deterring factor when addressing a veterinarian could be the cost of the performed work.

{*A*} – animal

As influence factors, the following key element of {*A*} has been used as on these components the range of changes when designing a technical device depends.

$$\{A\} = \{PP\} \cup \{TF\} \cup \{NA\}. \quad (3)$$

1. An animal depends on the breed which, in its turn, is divided by the physical parameters {*PP*}, namely mass and height [24].
   Dog classification by breed:
   - very small;
   - small;
   - average;
   - big;
   - very big.

   Dog classification by mass:
   - under 5 kg;
   - 5-10 kg;
   - 10-20 kg;
   - 20-30 kg;
   - 30 kg and over.

   Dog classification by height:
   - under 30 cm;
   - 30-40 cm;
   - 40-56 cm;
   - 56-65 cm;
   - 60 cm and over.

2. During urine collection, the type of fur {*TF*} of the dog is no less important [1]. Dogs can be:
   - nonhairy;
   - smooth-haired (Great Dane);
   - short-haired (chihuahua);
   - dogs with skin folds (shar-pei);
   - dogs with wild-type fur (Alsatian);
   - long-haired dogs with silky fur and little underfur (Japanese Chin);
   - long-haired with a lot of underfur (Pekinese);
   - dogs with long, thin and soft wool (Afghan hound);

- dirty dogs with rich, rather soft fur (bobtail);
- dogs with poodle-like wool (poodle);
- dogs with string or laminar wool (koolie);
- stiff-haired dogs with short wool (smooth fox terrier);
- stiff-haired dogs with straight mid-length wool (schnauzer);
- stiff-haired dogs with rigid curly wool (Airedale);
- curly dogs with short wool (curly retriever) [25].

In long-haired dog breeds, urine may partially pass through fur around the genitalia where urethra exits. This could influence the sterility of a sample, because there is always microflora on fur.

3. A significant place is occupied by the type of higher nervous activity {*NA*} of an animal (temperament) [7]:

Table 1

Dog temperaments

Characteristics	Temperament type
Strong imbalanced type	Choleric
Balanced fluid type	Sanguin
Strong balanced inert type	Phlegmatic
Weak type	Melancholic

It is necessary to take the abovementioned elements into account in case of adverse events that can emerge during the contact with the animal due to incorrect positioning or movement of a contact person {*P*}. However, one also should not forget about the quality indicators of the process.

{*M*} – means of execution

During the examination it has been established that a successful execution is impacted by the state of the animals – calm, excited or transitory; plus, the dogs are different from each other in the size and age. Presently the most widespread methods of urine collection are the following.

$$\{P\} = \{UC;MP;KT;TD\}. \quad (4)$$

1. Urine collection using a catheter {*UC*} – this type of urine collection is undesirable.
2. Method of direct urine bladder puncture {*MP*} – this type envisages that it is to be performed by a veterinarian to avoid health hazards for the animal.
3. Collection from the tray {*KT*} – this method envisages holding preliminary disinfection to ensure the tray's cleanliness.
4. Collection using special technical devices {*TD*} is performed by the owner or a veterinarian without disturbance for the animal.

Based on the received data about different types of performing the procedure, we organized them and made a decision about further directions of work according to the provided characteristics. At that, it is important to take into account the peculiarities of each way (process) and conditions it is performed in. The efficiency, as we can see, is determined by multiple criteria.

{*T*} – technical device

A technical device for urine collection is necessary and popular despite their variety and active use. It is especially important in case of isolated use, when it is necessary to control the course of the whole process at the same time.

A first-priority task is determination of construction characteristics, which envisages familiarization with the process using each technical means and determining the productivity of their work. Based on that familiarization one can single out the peculiarities of constructions in the course of use.

The difference between technical means is the following:

- they have a telescopic handle but the same diameter of vessel the material is collected in;
- there is a possibility to change the vessel for urine collection, but the holder has fixed length;
- they are equipped by a changeable holder and collapsible ring with fixed diameter [26].

After synthesis of the technical means reviewed and construction features differentiated, it becomes possible to offer a new constructive solution that will radically improve the current task of urine collection in a sterile vessel depending on its dimensions.

{*V*} – vessel

Using different vessels offered at the market encourages us to search for new ways in construction of technical devices, in particular according to the following features:

$$\{V\} = \{CV\} \cup \{PM\} \cup \{MT\} \cup \{EI\}. \quad (5)$$

1. Depends on the container volume {*CV*}: 60 ml, 120 ml, 125 ml, which in their turn have different diameters.

   Different cover diameters and materials it is made of impact the ways of its attaching to the vessel – screwing on or close adhesion.
2. Possible materials {*PM*}:
   - plastic;
   - polypropylene;
   - glass.
3. Material transparency: transparent or opaque {*MT*}.

   Vessel sterilization and the method used for the process, e.g. radiation.
4. Availability of interval scales and labels for entering information {*EI*}.

It is also important to take into account the reasonability and possibility of additional thermal processing of the vessel during the collection. Therefore, we have taken into account all possible factors when modeling the selection process as a whole. This has been achieved by reviewing characteristics and parameters, establishing the dependencies and analyzing their impacts.

Based on the system provided above with regard to all components, the urine collection technological process has been modeled with its impact on the quality of the obtained biomaterial established. Strengthening of requirements for the process demands greater durability of components and reliability of their joining which annihilate the differences {*V*} cited above. One of the solutions is the development of an efficient device with regard to mutual location of components. These requirements should be adhered to for optimal distribution of the load at the point of contact.

Technical device improvement is in the search for the best parameters of actionable requirements with regard to the tasks put forward.

The methodology of a technical device design consists of several stages:

- an idea is generated from the formed knowledge base;
- the most feasible option is constructed out of all possible ones;
- possibilities of adaptation to parameters are taken into account, with the prospect of their change depending on the object;
- study of operation parameters.

The use of search to form a knowledge base for modeling the structure of technological processes envisages analysis of features and parameters allowing to establish many important characteristics, and also the boundaries of their change (Fig. 3). At the first stage, the information base on the animal is formed.

At the second stage, the input information is evaluated. The mechanism of this stage is represented by a person performing the procedure, who shows his competence with the help of available practical experience.

At the third stage, an evaluation of the process selection is performed. The mechanism of this stage is disclosed in the management of the technological process with the possibility of improvement.

The formation of a set of measures to improve the level of management for the purpose of designing the technological process of urine collection, which includes the design of a device for collecting urine from dogs, as well as the formation and use of financial and labor resources, is the last stage for obtaining a strategy for modeling the given technological process.

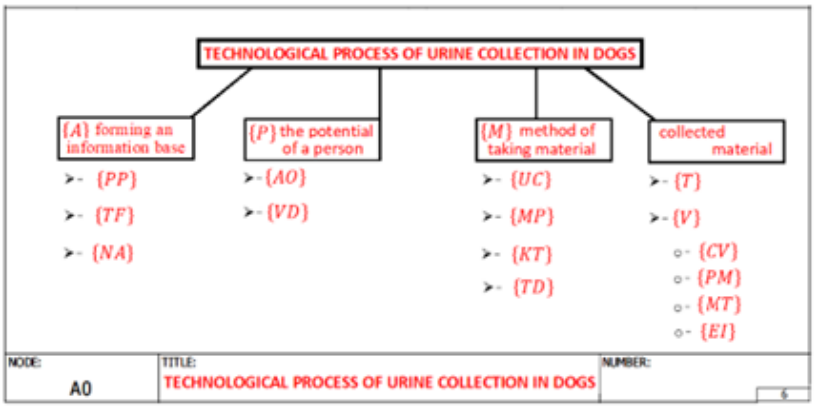

Fig. 3. **Model of the technological process of urine collection in dogs**

Therefore, this enabled us to decide on innovational development, which allowed us to improve the urine collection device for dogs based on our research [26] (Fig. 4).

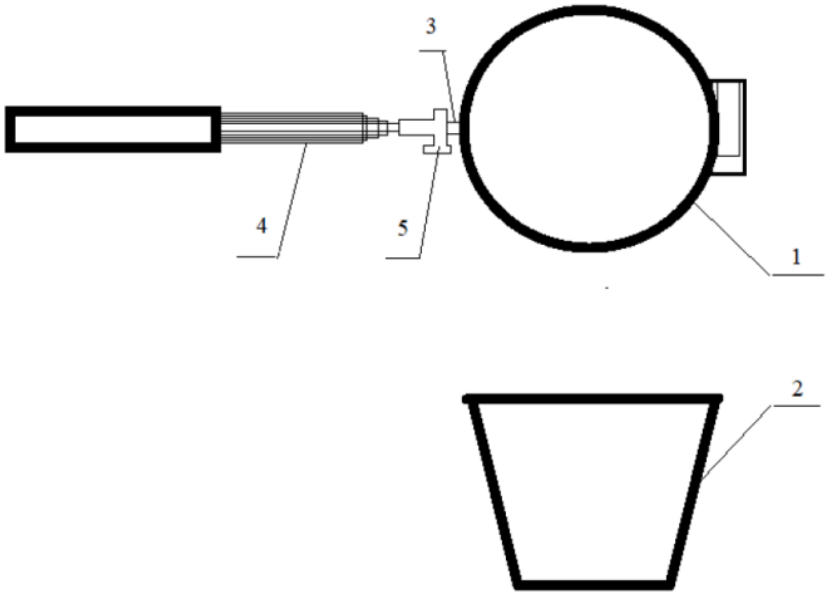

Fig. 4. **Improved device for urine collection in dogs:** 1 – turn buckle; 2 – vessel for urine collection; 3 – holder, 4 – collapsible hose; 5 – screw fastening the holder

The use of this device optimizes the urine collection procedure and prevents human contact with animals' biological substances.

A distinguishing feature of the offered urine collection technological process model for dogs is that using the combination of set elements combining processes, means, objects and phenomena of the model, a new solution for the given tasks is specified, a device has been developed allowing to select optimal dimensions depending on the animal's breed.

The purpose of the modeling was to determine the weakest and most vulnerable places of the studied process, to analyze the advantages and the degree of necessary changes in it.

Based on the obtained model, thanks to the analysis, flaws in the technological process were identified, which do not allow it to be carried out effectively, and directions for improvement, correction of flaws and structuring of regulatory mechanisms were established.

Conclusions

1. A general model of the urine collection technological process has been developed. The proposed SADT model allows to formalize the process of urine collection, to implement partial measures aimed at improving the conditions of the technological process.

2. A description of the model components has been provided, allowing to view them as a vector of technical support.
3. The implementation will allow to obtain a convenient means of urine collection in dogs of different breeds using vessels of different volume.

Author contributions

The contribution of each author. Conceptualization, O.D., N.K. and T. L.-K.; methodology, O.D., N.K., T. L.-K. and S.K.; validation, O.D.; data curation, O.D. and T. L.-K.; writing original draft preparation, O.D. and N.K.; writing – review and editing, O.D., N.K. and S.K.; visualization, O.D. and M.M.; project administration, O.D.; funding acquisition, S.K., T. L.-K. and M.M. All authors have read and agreed to the published version of the manuscript.

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