
THE NATIONAL ANIMAL HEALTH MONITORING SYSTEM

A Source of On-Farm Information

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Information relevant to animal health is in high demand by a wide range of entities. Their needs range from specific details of a rare disorder to general descriptions of husbandry practices. The information is used for everything from the daily, detailed decisions of an individual producer to industry-wide education campaign efforts. To be useful, information to meet these needs must be timely, factual, and scientifically based. In the absence of reliable information, decisions are guided by individual perceptions, which may not reflect reality.

The Animal Industry Act of 1884 charged the Bureau of Animal Industry (the USDA: Animal Plant Health Inspection Service's [APHIS] predecessor) ". . . to investigate and report upon the condition of the domestic animals and live poultry in the United States . . . and to collect such information on these subjects as shall be valuable to the agricultural and commercial interests of the country (7U.S.C. Sec. 391)." Interpretation of this charge has led APHIS to develop various monitoring and surveillance strategies in the United States. The National Animal Health Monitoring System (NAHMS) program is one answer to this charge.

In 1974, the National Academy of Sciences published a report calling for the creation of a nationwide system for animal health surveillance.¹ The report was the work of a special panel that was created as a result of an earlier report published by the National Academy of Sciences,

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which included a review of existing information available on animal health in the United States.² The panel was charged with designing a nationwide system for the continuous surveillance of animal health. They recommended that a center be formed to serve as the focal point for collecting, compiling, analyzing, and disseminating information on the incidence, prevalence, and costs of animal disease. This recommendation has come to fruition in the formation of the Centers for Epidemiology and Animal Health (CEAH) in Fort Collins, Colorado, which houses the NAHMS national program staff.

THE PILOT PHASE OF NATIONAL STUDIES

In addition to traditional disease eradication and control programs, Veterinary Services (VS) initiated an animal health monitoring program that was aimed at developing a national animal health surveillance system in the United States. VS started what is now named NAHMS as individual state pilot projects in 1983. These projects were implemented state by state, based largely on the level of interest and initiative within the state. During the pilot phase from 1983 to 1989, seven states conducted studies consisting of approximately 1 year of data collection on farm for each year they participated. The pilot projects focused on various classes of livestock* of interest and importance within the participating state. Each participating pilot state designed and coordinated the project through their local college of veterinary medicine under a cooperative agreement. In some cases, participating producers were randomly selected (using list frames or geographic sampling methods) within each state and approached to voluntarily participate in each study. In other cases, a convenience sample of producers was selected to participate. The first data collection did not include collection of biologic specimens. This feature was added to help detect and validate the occurrence of specific conditions. These early efforts demonstrated that federal and state animal health officials could collect valid useful information on animal disease occurrence and costs in each state and further that this information could be presented in tabular descriptions of disease occurrence and associated costs for the state.³ The results were then available for use in producer and veterinarian education programs and to help define research needs.

The pilot studies succeeded in establishing the feasibility of conducting large-scale animal health surveillance systems using the infrastructure of government veterinary services.³ Some weaknesses in such a system were identified, including acquisition of minimal production-level information, so that interactions among animal health and productivity were not addressable; the inability to develop regional or national summaries of findings because each state selected producers differently

*Studies collected data on dairy cattle, cow/calf, beef feedlot, sheep feedlot, sheep, turkey, swine, and goat operations.

and defined their implementation differently; inability to calculate the costs of reducing or preventing diseases or the overall profitability of each operation; and establishing objectives set for each data collection that were not always of interest to the participating producers. Producer evaluations revealed that monetary compensation was less desirable than other benefits (such as biologic sampling results) as incentives to participate.

The pilot phase ended in 1989 and led to a redirection of efforts to establish a national level program with central design and coordination for each study.^{4,5} CEAH was formed by adding NAHMS program staff to the existing National Center for Animal Health Information Systems staff in Fort Collins, Colorado. Swine was chosen as the first class of livestock to be studied in the new national program primarily based on industry encouragement and involvement. People representing all facets of the swine industry were included in discussions to determine the focus of this first national study. The study objectives were to provide information on the production and health levels of U.S. swine and to identify factors influencing preweaning morbidity and mortality. States were selected for participation based upon their previous involvement in pilot studies as well as their contribution to the total U.S. swine population. Potential participating producers in selected states were randomly selected from list and area frames maintained by the National Agricultural Statistics Service (NASS) and asked to volunteer for the study. Those agreeing to participate in the first phase of the study provided retrospective information on health and management practices on their farm via questionnaires administered by NASS personnel. Those agreeing to participate in the second phase provided both retrospective and prospective information to state and federal animal health officials between December 1989 and January 1991. Each farm was visited a total of four times over a 90- to 120-day period during the second phase. Producers recorded observations of clinical signs associated with illness and death in sows, gilts, and preweaning piglets on diary cards for 21,712 cohort litters. Producers agreeing to biologic specimen collection had serum tested for TGE and water samples tested for nitrates and heavy metals. Results of biologic testing were returned to producers. The study results were released in November 1991 in the form of several short fact sheets and one descriptive report consisting of a series of tables of compiled data.

Once the swine study was underway, efforts were immediately started to define the study objectives for the first national dairy study. Based on input from those representing various aspects of the dairy industry, the objectives of this study were to describe heifer health and management on U.S. dairy farms. The same general procedures were followed as had been used for swine, with retrospective data collected via NASS and on farm health data collected by state and federal animal health officials between April 1991 and July 1992. Biologic specimens collected included blood and feces that were tested for immunoglobulin levels, selenium, cryptosporidium, *Salmonella*, and *E. coli* O157:H7.

NATIONAL STUDIES TODAY

With two national studies initiated and at least partially underway, efforts were increased to streamline the national study process and decrease the turnaround times associated with the new national program. The completion of one study every 2 years, and having each study take over 2 years from inception to release of results, was certainly less than ideal. The methods employed by the NAHMS program have been continually evolving. Throughout all of these changes, the NAHMS program continues to be a nationally driven initiative to generate statistically valid and scientifically sound national and regional estimates of various on-farm, health-related practices for specific animal commodities. NAHMS studies are geared to provide a limited amount of core trend information across years and to target critical issues for major U.S. livestock industries. NAHMS studies generally include on-farm interviews and biological or environmental specimen collection. Producers are selected at random from sampling frames provided by the USDA's NASS and are first contacted by NASS representatives. Producers agreeing to participate in NAHMS studies are guaranteed confidentiality and receive national study results and laboratory test results for their operation. States continue to be selected to participate in NAHMS studies such that a minimum of 70% of the animals in the United States and 70% of U.S. operations having those animals are represented.

The major U.S. commodities are studied on a rotating basis with no more than two commodities targeted for inclusion each year. These rotations have been set to minimize the chance that any state will have to simultaneously conduct more than one study or that studies will occur back to back in key states. Efforts are also underway to more fully utilize existing data sources and as such, the rotational scheme is being matched to the cost of production survey work performed by USDA's Economic Research Service. As the U.S. livestock population shifts and as nontraditional species gain in popularity, these rotations may be altered. At present, each commodity covered by NAHMS will be considered for inclusion in a national study once every 5 years.

Once a commodity has been targeted for study, efforts to define the study focus and objectives are initiated 12 to 18 months in advance. These efforts have evolved to include multiple focus groups composed of key stakeholders (industry, allied professionals, academia, regulatory officials, and producers) who are asked to identify information needs and gaps, questionnaires for individual producers to indicate their needs, and networking within the industry to identify issues that are important. All of this information is gathered and evaluated to determine potential objectives that would best be handled through a national study approach. Consideration is given to both long-term monitoring objectives as well as short-term objectives. If such objectives are found, they are prioritized, and those of high priority and feasibility are included in the study objectives. Objectives must be of interest to producers and to the producer organizations because study participation hinges

on the study having a high perceived value for the industry as well as for the participating producer. If no such objectives emerge, either for long-term monitoring or for immediate needs, no national study is conducted for that commodity in that year, and that commodity is not slated for national study for another 5 years. In cases in which only long-term monitoring needs are identified, it is possible to conduct a national study with no on-farm component, and data may be collected via telephone or mailed questionnaire. In those cases in which no component of a national study is indicated, there may be other types of studies initiated that more appropriately and efficiently address the needs of the industry. The commodity rotation for NAHMS national studies through 1999 is shown in Table 1.

If a national study is to be conducted, specific and detailed study objectives are set 6 months prior to the onset of initial data collection by NASS in order to allow for development of actual questionnaires. These objectives then dictate the study design (number of visits, time of year, specimen collection, and special screening criteria for inclusion in the study such as size, geographic location, or type of production) as well as provide a framework for the questionnaire development. By 5 months prior to the study, the study design as well as a draft of general and screening questions will have been developed by the NAHMS national staff in collaboration with other commodity experts. These questionnaires are further refined and pretested by NASS with selected producers and are revised before the actual study is initiated. Once the questions have been finalized for the first phase of the study, NASS enumerators are trained on the study objectives and questionnaire content. The first phase of the study generally involves an initial set of management-related questions as well as any screening questions if subsequent phases of the study are only directed at certain types of producers. NASS enumerators ask producers who meet the screening criteria if they will consent to have their name turned over for contact by an APHIS representative. This first phase of data collection occurs over a 2 to 4 week

Table 1. NAHMS NATIONAL STUDY COMMODITY ROTATION

Year	Commodity 1	Commodity 2
1989	Swine	
1990		
1991	Dairy cattle	
1992		
1993	Beef cow/calf	
1994	Cattle on feed	Poultry-layers*
1995	Swine	Sheep*
1996	Dairy	Poultry-broilers*
1997	Beef cow/calf	Aquaculture (catfish)*
1998	Equine	Poultry-turkeys*
1999	Cattle on feed	Poultry layers

*No on-farm study planned.

period. During the next contact, subsequent phases of the program are explained, and producers are offered the option to continue participation. The next phase of the study usually involves on-farm interviews and biological or environmental sample collection by state and federal animal health officials.

State and federal animal health officials are involved in pretesting the questionnaires. Each state has an animal health official who serves as the study coordinator and is provided training on the study's purpose and methods. These coordinators are then responsible for training all of the data collectors within their state and reviewing the completed questionnaires and forms for consistency and accuracy. Once reviewed, the completed questionnaires, identified only by farm number to help assure confidentiality, are sent in to the NAHMS national staff for further review, data entry, and validation. The coordinators and national staff work closely together to ensure that accurate information is recorded for each operation participating in the study.

Producers who agree to participate in the second phase of each study are asked to complete a producer agreement allowing the state or federal animal health official who has contacted them to collect the necessary information. The agreement stipulates that the information collected will be kept confidential. The one exception to this confidentiality is that if a foreign animal disease is suspected or diagnosed, the producer will be subject to further action as appropriate. The information collected from the producer, including biologic samples, will not be used by APHIS for regulatory purposes. The study findings will be published for the benefit of the industry and other interested groups in such a way as to guarantee that the identity of individual participating producers can not be discerned. The producer will get copies of the overall study results and will be asked to complete an evaluation of the study. The producer is given a further option to participate in any or all of the biologic sample collections that might be part of the study. Tests run on these samples are either in direct support of the study objectives or are designed to be producer incentives for participation. Generally, participating producers are given the results of biologic sample testing for their farm. In a few cases where fecal samples have been tested for *E. coli* O157, results have not been returned to producers because there are no animal health concerns associated with this organism, there are no scientifically based steps that producers can use to decrease levels of shedding, and some producers may feel an ethical dilemma related to sales of animals that are known to shed this organism.

Laboratory testing for the national studies is generally conducted at the National Veterinary Services Laboratories (NVSL) located in Ames, Iowa. NVSL also conducts routine official testing and is involved in outbreak situations supporting other APHIS objectives. Because of competition for resources at NVSL, limited laboratory capacity or problems with timeliness of sample processing due to other priorities, other laboratories may conduct some of the testing. In some cases, the study time frame can be altered and avoid the need to use multiple laboratories by

spreading the large number of samples required over a longer time period.

The bulk of the data collection activities are completed by the state and federal animal health officials located in the participating states. Their participation, support, and understanding of the study is key to the success of the program. As time and interests permit, they are involved in the design and development of the individual study. They are also encouraged to work with their local university and extension specialists to develop local and regional add-ons to the program and to assist with disseminating the results following study completion.

The data are entered by NAHMS national program staff. Past attempts to have data entry conducted closer to the source of the data have proven inefficient and more costly primarily because of the small volume within each state. Validation procedures are conducted to ensure accuracy of the information entered. After validation, the data are analyzed, and national estimates are created. Further analyses identify risk factors associated with particular conditions. The results of these analyses are published in various formats including one-page fact sheets describing specific production management activities, descriptive data tabulations, and scientific articles in refereed journals. The national program staff maintains a mailing list by commodity of interested individuals, and these reports are sent out to those individuals as well as to industry journals and placed on a web site in order to widely disseminate the study findings.

Efforts are made to complete and distribute these reports in a timely fashion. Much of the analysis work needed to produce the reports as well as an outline of the reports themselves is drafted well in advance of actually receiving the data. This has allowed the dissemination of results to occur much sooner following completion of data collection than was possible in the earlier studies. For instance, results of questions asked by the NASS enumerators are now distributed within 4 months after data collection and before the end of the second phase of the data collection. In the recently completed Dairy '96 study, questions on management practices were asked in January 1996 by the NASS enumerators, and the results were disseminated in May 1996, just as the state and federal animal health officials were completing their on-farm data collection.

Results of these national studies are in high demand. Baseline information gathered as part of the national studies is used for a wide variety of analyses and further studies. Trend reports have shown changes in health conditions from the first study to the second 5-year study for swine and dairy. Data are also used to address emerging situations such as the occurrence of "weak calf syndrome" in 1993, the 1993 *Cryptosporidium parvum* outbreak in Milwaukee, and a new recognition of peracute bovine viral diarrheal (BVD) disease in 1994. Most of the biologic samples collected as part of the national studies are banked for future use and are useful in retrospective evaluations of new conditions and further work on endemic conditions.

The Portfolio Approach

National monitoring efforts require considerable resources to design and develop, train data collectors, implement data collection, analyze data, and disseminate results. Because of costs, the frequency and nature of NAHMS national studies are limited, and only a few scientifically worthy issues can be addressed. To date, resource constraints have limited study of any particular commodity, such as dairy cattle, to once every 5 years. Certainly this system is less than ideal to monitor trends that fluctuate more frequently than 5-year cycles.

Given these constraints, the relative merits and costs associated with other options for filling the information gaps not addressed by NAHMS national studies have been considered. To date, several ongoing monitoring activities have been investigated, and a few are employed in a "portfolio" of monitoring and surveillance activities. These activities are relatively of low cost, and wherever possible, use existing data sources. They are often restricted to a limited inference base.

Diagnostic Laboratory Disease Reporting

The Veterinary Diagnostic Laboratory Reporting System (VDLRS) has been used to report test results from 28 voluntarily participating laboratories from across the United States. The VDLRS has included five disease conditions for which standardized case definitions have been agreed upon by the American Association of Veterinary Laboratory Diagnosticians' subcommittee on Animal Disease Reporting. These data and limited interpretations were reported quarterly in the *Dx Monitor Animal Health Report*. Although the denominators for veterinary diagnostic laboratories data are difficult to determine, these data are useful in describing the geographic distribution of reported cases of monitored diseases and relative changes in the diagnosis of certain diseases. Participating laboratories are also encouraged to report unusual patterns in laboratory accessions in an attempt to gather information on emerging animal pathogens and conditions. In addition, the VDLRS provides a framework or network for conducting surveys when an emerging trend is thought to be developing. Data gathered through the VDLRS have been requested by pharmaceutical companies interested in developing new products. The VDLRS is currently undergoing some revisions as the United States develops a formal reporting system for Office International des Epizooties (OIE) listed diseases. The *Dx Monitor* will continue to report the status of regulatory diseases and interesting case reports from laboratories until the new formal reporting system is designed and implemented. The new reporting system is expected to remain somewhat dynamic for a number of years and may include important conditions in addition to those listed by OIE.

Sentinel Cattle Feedlot Reporting

This voluntary system involves monthly death loss reporting by consulting veterinarians working in cattle feedlots. Currently eight consultants report on mortality in 55 to 60 feedlots, which accounts for roughly 1.5 million head of cattle on feed (approximately 15% of the total U.S. cattle on feed population). Participants submit confidential monthly reports of death loss for each of their operations and, in turn, receive a report on trends in their operations and overall trends for all participating operations. This reporting system allows limited monitoring for the emergence of feedlot death loss trends. The system itself is relatively of low cost and, similar to the VDLRS, sets up a network of contacts for more targeted monitoring and specific studies when an emerging trend is identified.

NASS Inventory Information

This information is generated semiannually for cattle and quarterly for sheep and swine and is used as an estimate of the total population of each species of livestock. Inventory information is most useful as a current, maximum figure for the population at risk and gives national- and state-level estimates on livestock location (for both individual animals and herds). In general, estimates are published by animal weight class, herd size, location (state), and numbers of producers.

NASS Death Loss Studies

In a collaborative effort between NASS and APHIS, questions have periodically been added to some of the NASS inventory questionnaires to collect information about the most common reason for loss of various classes of livestock. To date, reasons for loss of cattle and calves have been surveyed twice (1991 and 1995) and sheep losses have been surveyed once (1994) with state level estimates published. In the interim periods NASS provides administratively confidential data to NAHMS on the losses of cattle and calves by operation type to allow some ongoing monitoring of trends. Plans call for an expansion of this collaboration to include other classes of livestock.

National Poultry Improvement Plan (NPIP) Breeder Pathogen Information

Data compiled through NPIP on the prevalence of certain *Salmonella* and *Mycoplasma* species in breeder flocks are graphed to follow trends in the number of flocks monitored, the number of birds monitored, and the flock prevalence of these diseases.

Somatic Cell Count (SCC) Information from the Dairy Herd Improvement Association (DHIA) and the USDAs Agricultural Marketing Service (AMS)

DHIA has provided annual summary milk somatic cell count information, whereas AMS supplies monthly producer-level information. The AMS oversees use of SCC information in milk pricing schemes in some parts of the country. Bulk tank samples of milk are laboratory tested, and averages will be evaluated over time by herd size and geographic area. SCC monitoring provides a gauge of dairy udder health and milk quality and may allow the detection of emerging conditions.

Food Safety Inspection Service (FSIS) Slaughter Condemnation Data

FSIS routinely records carcass condemnation information for cattle, swine, sheep, horses, and poultry, which is useful in evaluating trends in the occurrence of nonfatal conditions among animals that are subjected to federal inspection. In addition to monitoring changing patterns of these conditions (geographic, slaughter class, etc.), the data can be used to answer specific epidemiologic questions. This monitoring has also led to the implementation of a targeted study (Marek's disease) to investigate a trend.

Mycotoxin Levels in Corn

The 1994 corn crop in Iowa was monitored for mycotoxins, with additional states added in 1995 and 1996. Just prior to harvest, ears are picked from randomly selected fields and plots for the NASS Objective Yield Survey. The corn is tested at NVSL, and findings are published in a fact sheet format each December.

Summary

Owing to declining budgets in the face of demands for continued and, in some cases, increased services, the NAHMS program is constantly evaluating ways to streamline existing efforts and to implement new ongoing monitoring systems that represent additional critical pieces in the attempt to have a coherent system to monitor health status.

Targeted Studies

In many cases, it is enough to monitor and report trends observed and detected through various means. Often, however, these trends raise further questions about relevance, cause and effect, pertinent risk factors, and myriad other topics that can only be adequately addressed through careful epidemiologic studies aimed at answering specific questions. National probability-based, cross-sectional studies and ongoing monitor-

ing systems are used to identify trends, detect potential risk factors and generate hypotheses. Targeted epidemiologic studies represent an efficient way to provide timely information on critical issues for the livestock and poultry industries.

Some targeted follow-up studies born out of national study or ongoing monitoring findings are conducted in controlled, experimental conditions. Universities and other research institutions conduct smaller-scale field studies to further test hypotheses generated through national study and ongoing monitoring activities. USDA:APHIS:VS conducts a limited number of follow-up studies when such studies are within the scope of agency missions and goals. An example of a VS-targeted study that grew out of a national survey involved risk factors for *E. coli* O157:H7 shedding in dairy heifers. The targeted study was inspired by the existence of related data from the 1991 NAHMS National Dairy Heifer Evaluation Project.

Targeted studies could be any one of the full range of potential epidemiologic studies (case-control, cross-sectional, or cohort). Case and control animal units could be selected based on data collected during a national study, through an ongoing monitoring system (such as the VDLRS) or by other means. Sample units for cross-sectional or cohort studies could be developed based on information collected during national studies or through another sampling method. The existing collaborative relationships that NAHMS has with other government and non-government units makes the prospect of these types of studies very feasible.

Future targeted studies will focus on areas related to the mission of APHIS. To date, targeted studies have focused on food safety issues (*E. coli* O157), animal health concerns (peracute BVD, Marek's disease, and weak calves) and product wholesomeness (eosinophilic myositis).

FOOD SAFETY INFORMATION FROM NAHMS

In the past, NAHMS has collected data to address food safety concerns. Previous studies have focused on *E. coli* O157 (dairy heifers, feedlot cattle, swine, adult dairy cattle), *Salmonella* (dairy heifers, swine, feedlot cattle, adult dairy cattle), *Campylobacter*, *Listeria*, and *Yersinia*. In addition, though not strictly a food safety pathogen, *Cryptosporidium* shedding by animals has been addressed (dairy heifers, beef calves). Generally, the intent of these studies has been to describe the prevalence and distribution of the agent and to evaluate potential risk factors for shedding. Table 2 shows the number of participating producers for each of the national on-farm studies completed through 1996.

The NAHMS focus on food safety pathogens in previous studies has been based on the need for additional information about the epidemiology of the pathogens on farm. Because NAHMS is a voluntary program that depends entirely upon the cooperation of the commodity groups, their support of addressing food safety issues was sought prior to study initiation. In addition to commodity group concerns and considerations, the roles of various federal agencies impacts these studies. As

Table 2. NUMBER OF FARMS INCLUDED IN NAHMS STUDIES WITH FOOD SAFETY-RELATED PATHOGEN TESTING: 1989–1996

Year	Commodity	Participating Farms* by Phase		Sample/Pathogen(s)
		NASS/APHIS	Farms Sampled	
1991	Dairy	1,811/1,123	1,063 1,103	feces/ <i>E. coli</i> O157 & <i>Salmonella</i>
1993	Dairy followup		64	feces/Cryptosporidium
1993	Beef cow/calf	799/495	200	feces/ <i>E. coli</i> O157
1994	Feedlot cattle	1,411/453	100	feces/Cryptosporidium feces/ <i>E. coli</i> O157 & <i>Salmonella</i>
1995	Swine	1,477/418	152 297	feces/ <i>E. coli</i> O157 & <i>Salmonella</i> feed/ <i>Salmonella</i>
1996	Dairy	2,542/1,219	91 90	feces/ <i>E. coli</i> O157 feces/ <i>Salmonella</i>

*Participating farms are those that completed the entire set of questionnaires for each phase of the study.

the U.S. government adjusts to the various forces impacting it, the structure in place today could be drastically changed in the future. In addition to the actual organizational structure, the individual yearly appropriation bills from the U.S. Congress can and have had specific language inserted directing a particular agency to complete specific activities or to refrain from conducting specific activities.

The need for continued collections of information handled through the NAHMS program is expected to remain. With the continued collection of information concerning conditions of livestock, domestic animals, and poultry, there will be opportunities to continue to examine related issues of food safety. Potential risk factors identified through various means can be quantified within the U.S. livestock population using NAHMS studies. When possible, potential risk factors for food safety pathogens and conditions can be looked at as a specific objective of a NAHMS national study. Additional studies can also be designed to further evaluate pathogens and specific risk factors when such efforts cannot be completed under the auspices of the NAHMS national study program. In addition, serum and isolate banks filled through the NAHMS program can be considered for use in cases in which the issue at hand will not jeopardize the NAHMS program for the future.

CONCLUSION

Given the high demands for scientifically accurate and timely animal health information, the portfolio strategy of combining national

studies, ongoing monitoring, and limited, targeted studies is anticipated to provide modern agriculture with the most complete and economical approach to information needs possible. Although national studies provide statistically valid estimates of a wide range of potential risk factors and practices at specific points in time and over time when repeated, ongoing monitoring is a useful tool for keeping a watchful eye on trends that might be developing more rapidly in selected areas and provides the framework and network on which to build targeted studies. In turn, targeted studies allow further evaluation of specific hypothesized relationships between health outcomes and suspected risk factors. National studies, ongoing monitoring, and targeted studies combined are helping paint a more complete picture of animal health in the United States.

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