Quality Assurance in Mortality Composting, Mortality Composting Safety

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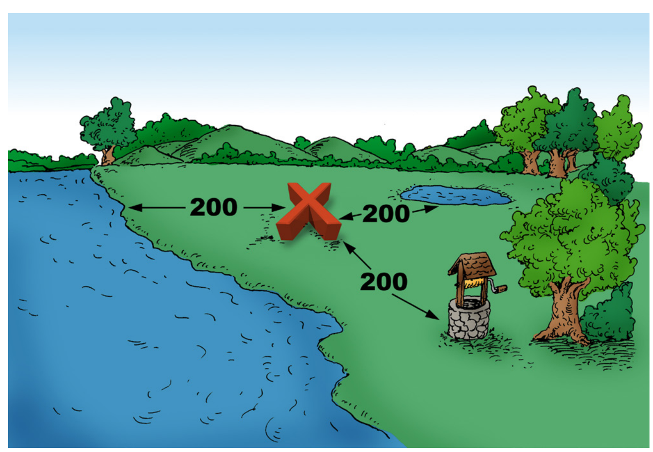
Mortality Composting Procedure

Composting is the aerobic, or oxygen requiring, decomposition of organic materials by microorganisms under controlled conditions. Microorganisms consume oxygen while feeding on organic matter and, as a result, give off heat and carbon dioxide. In conventional composting, operators manage the process variables, feedstocks, air, moisture and shelter, to optimize the slow natural decay process (i.e., when these elements are out of balance). Green, wet, nitrogenous feedstocks are mixed with brown, dry, carbonaceous material creating a carbon to nitrogen (C:N) ratio in the range of 20 to 30:1 along with the proper amount of moisture. The windrows or piles are then managed via monitoring and turning for proper air-flow and temperature in order to speed up decomposition, eliminate odors, and destroy pathogens and weed seeds. Mortality composting does not follow the rules of starting with a "mix" of the right moisture and C:N ratio. In mortality composting, the diet is all wrong (C:N about 50:1), air flow occurs passively, and moisture comes from the carcass as it decomposes. Instead, an envelope of carbon material simply allows the natural process of decomposition to occur in a manner that will absorb the moisture and odors emitted when carcasses decay.

Composting of mortalities started in the late 1980s when Dr. Dennis Murphy at the University of Maryland designed a successful poultry composting facility using a series of bins. Other methods of composting dead birds, including windrows, were quickly adopted. Using these same principles, composting of larger animals was explored. Its adoption was much slower because there were standards stating that only pieces of flesh less than 25 pounds could be composted. Eventually the standards were changed and it was found to be effective and economical for all animal mortalities. The basic procedure for composting of carcasses is as follows:

1. Select the site away from ground and surface water.
2. Prepare the base of carbon.
3. Place the animal in the center and cover.
4. Layer young and/or small animals and cover each layer.
5. Let sit 4 to 9 months.
6. Use the composted material.
7. Reuse bones/un-composted material for the next base.

When selecting a location for mortality composting keep in mind that a good site will encourage thermophilic (104 to 140°F; 40 to 60°C) composting, protect the environment, and give workers the ability to monitor and manage both the piles and the site.



Select a site that is well-drained and at least 200 feet from water sources with a slight slope.

Windrows are positioned to run with the slope to allow runoff water to move between piles. Berms and a lagoon protect ground and surface water.

Select a site that is well-drained and away from watercourses, sinkholes, seasonal seeps, or other landscape features that indicate the area is hydrologically sensitive. Pads are level areas constructed of compacted soil, asphalt, or concrete. They have several purposes, including water quality protection, providing a good working surface, and allowing access through wet weather conditions. On most farms, moderate to well-drained, hard-packed soils with gentle slopes are well-suited as composting sites. A slope of about two percent is desirable to prevent ponding of water, which can be a breeding ground for mosquitos that act as vectors of some diseases and will produce odor on site. Steep slopes are not satisfactory because of potential problems with erosion, vehicular access, and equipment operation. Compost windrows should run up and down the slope, rather than across, to allow runoff water to move between the piles rather than through them. Ground and surface water can be protected using filter strips or grassy areas, compost berms or socks, and collection lagoons or tanks. Siting is very important to help avoid neighbor issues. Determine the dominant wind direction and if most airflow is directed toward populated areas, look for another site.

Preparation of the base is the next step in mortality composting. A 24-inch bed of bulky, absorbing organic material containing some sizeable pieces should be used. The base material should promote aeration of piles and bins and be thick enough to absorb the moisture generated above, while being able to maintain its structure with the weight of the carcass or carcasses. The size of the base should be large enough to allow for 24 inches of carbon material all the way around the carcass or carcasses. Next, lay the carcass on the base, or layer carcasses of young or small animals. Although any animal can be composted whole with minimal processing, preprocessing may speed up the composting process. It is a good practice to pierce the stomachs, especially the rumen, of cattle and other ruminants to prevent bloating and possibly explosion from accumulating gases. Total size reduction like grinding or chipping may expedite the process but requires specialized equipment, as well as additional worker health and safety requirements; it can be messy and unsettling and is not recommended.

Make the base large enough to allow for a 2-foot clearance around the carcass.

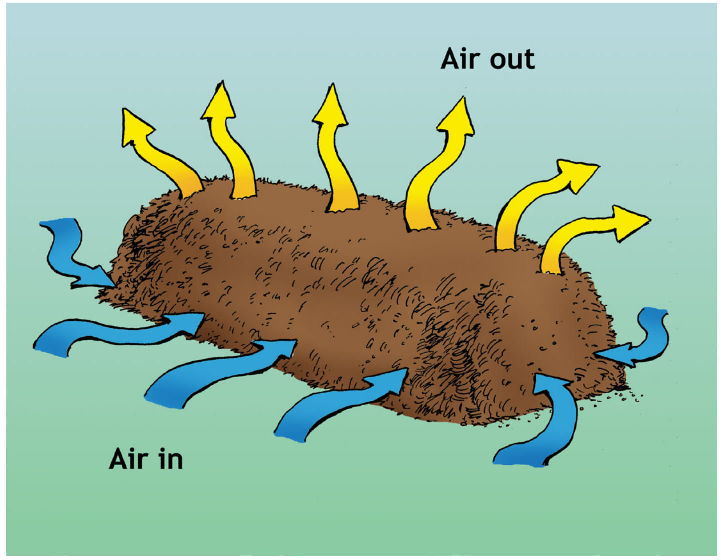
If composting in layers, cover each layer with 12 to 15 inches of carbon. Cover a single carcass or the last layer of carcasses with 24 inches of carbon. In dry climatic conditions water should be added to the amendments during pile construction. Some best management practices for building the pile include incorporation of dead stock in a timely fashion to deter pests and odors; build well-shaped, neat windrows; lay the base for the next carcass while composting the first but avoid driving on the next base to keep it from compacting. The finished pile should be 5 to 7 feet high. Make sure all mortalities are well-covered to keep odors down, insulate the pile and keep vermin or other unwanted animals out of the windrow.

Chunky carbon base laid out for next carcass.

Pile carbon sources

Potential feedstocks for on-farm mortality composting include animal bedding, waste feed, manure and poultry litter, straw, spent silage/hay and feed refusals, as well as woodchips, shavings, sawdust, and recycled compost. Good feedstocks will be relatively dry (< 50% moisture), have particles with some rigidity plus a large surface area, have a high C:N ratio (> 40:1), be non-attractive to pests, decompose well enough to produce usable compost, and have low bulk density (be porous). A well-built pile with good feedstocks will allow for thermal air movement and diffusion so that the composting process will proceed aerobically and optimally. Well-built piles will release little to no leachate (liquid that comes out of the pile), protecting ground and surface waters and remaining unattractive (i.e., no odor) to domestic and wild animals.

There has been a considerable amount of research on feedstocks. Bedding from animal pens – carbon material mixed with livestock manure – is the cheapest and most available feedstock on a livestock farm. Successful composting of dead swine (Fonstad et al., 2003), sheep (Stanford et al., 2000), and calves (Stanford et al., 2009) has been accomplished with straw/manure mixes and turkey carcass composting was successful with sunflower-hulls-based turkey litter (Rahman, 2012). Feasibility of year-round composting of lamb and mature sheep mortalities within the arid climate of the Canadian prairies was also looked at in terms of feedstock. In the winter, manure was wetter and more dense and decomposition tended to become anaerobic, indicating a need to add more carbon material for better aeration. Too much aeration from the carbon source can also reduce temperatures and slow down decomposition as was demonstrated over the winter in road-killed carcass piles in New York where wind speed was high and snow cover was minimal (Schwarz et al., 2010).



Natural air flow: pile heats, heat rises and fresh air is pulled in from the base.

Comparison of pine shavings, a 50:50 mixture of pine shavings and poultry litter, and hay as the carbon source for composting large animal carcasses showed that shavings and the 50:50 mixture maintained higher temperatures and were more effective at decomposing bones when compared to hay (Payne and Pugh, 2009). A comparison of biodegradability of swine carcasses in passively aerated composting systems using corn silage, ground cornstalks, and ground oat straw as the envelope material showed that after 16 weeks of composting only 66% of the initial carcass mass had decomposed in corn silage as compared to 86 and 79% in ground cornstalks and oat straw, respectively (Ahn et al., 2007). Further research using these same materials was conducted over three different seasons to assess time/temperature criteria for pathogen reduction (Glanville et al., 2013). Internal temperatures reached 131°F (55°C), (United States Environmental Protection Agency - US EPA - Class A time/temperature criteria for pathogen reduction) in 89, 67, and 22% of seasonal test units constructed with corn silage, straw/manure, or ground cornstalks, respectively.

Monitoring the pile

After constructing a mortality windrow/pile it should be monitored for the next four to nine months. A record of temperature, odor, vectors, unwanted animals, leachate, spills, and other unexpected events should be kept as a record of the process. This will allow the composter to see if sufficiently high temperatures were reached and adjust the process if there are any problems. Monitoring of the pile is done primarily by checking temperatures. Internal compost temperatures affect the rate of decomposition as well as the destruction of pathogenic bacteria, fungi, and weed seeds. The most efficient temperature range for composting is generally between 104 and 140°F (40 and 60°C). Thermometers with 3 to 6 foot probes and data loggers are available, although care needs to be taken when inserting them into the pile, as they can bend or break when hitting rock, bone, or dense material. Well-stacked piles should heat up in 12 to 24 hours. Depending on the size of the carcass, in the first two months the flesh substantially decomposes while temperatures increase to and remain at thermophilic levels for pathogen destruction. The meat is digested and there should be clean bones in month three or four. In most cases, the pile should be left undisturbed in this 4-month period so that odors and gases from decomposition are not released from the pile. After four months, the pile can be turned to help expedite the process or to combine several piles into one. This pile should then either be left for curing or can be spread out to become the base of the next pile.

Clean bones remaining in the compost pile after 4 months.

Safety and Mortality Composting

During pile building and monitoring, it is recommended that workers wash hands with soap and water before eating or smoking or whenever hands come into contact with compost feedstocks and care for cuts and abrasions promptly keeping wounds covered with clean, dry bandages. Excess contaminants should be removed from footwear prior to entering a vehicle or a building. Dust particles combined with airborne biological and chemical elements (bioaerosols) can cause chronic adverse health effects, ranging from skin or eye irritation to allergic reactions and illness. Keeping materials moist can help reduce this risk, and individuals with allergies, respiratory disorders or those that are immunocompromised should be aware and wear personal protective equipment (PPE) when performing duties that could release bioaerosols and dust. According to Brown (2006), the primary potential chemical hazards in the composting process are due to gaseous compounds released during decomposition, including: carbon dioxide, ammonia, nitrous oxide, methane, hydrogen sulfide, and carbon disulfide. These gases are health hazards when they are present in high concentrations or displace fresh air needed for proper breathing. In the normal environments of a composting site, these gases are generated gradually and either further decompose or dissipate well before accumulating at hazardous levels. However, high concentrations can occur in certain situations, such as inside composting vessels, enclosed storage bins or when an actively decomposing pile is opened. In these situations, the fumes can potentially overcome a worker. Building the pile properly and leaving it undisturbed for four months can allay this problem.

In situations where mortality composting is used for disposal of diseased animals, especially those that are zoonotic, other precautions should be taken. When possible, diseased animals should be composted close to the infected site and even in barns to ensure disease containment. Litter, bedding or other organic material should be composted along with the carcass(es). Persons with compromised host defenses, such as those with diabetes, cystic fibrosis, inherited immune deficiency, and others who are at greater risk of infection should be excluded from working with diseased animals. Appropriate PPE should be worn (based on the disease causing organism and routes of entry) to protect hands, body, head, feet, eyes and the respiratory system:

1. *Hand protection:* Wear impermeable gloves (lightweight nitrile or vinyl disposable gloves, or heavy-duty 18-mil rubber gloves that can be disinfected; use the glove appropriate for the activity). Avoid touching the face and mucus membranes, including the eyes, with gloved hands that have been contaminated. Change or discard gloves if torn, punctured, or otherwise damaged.
2. *Body protection:* Wear disposable outer clothing or coveralls with an impermeable apron over them, or wear a surgical gown with long, cuffed sleeves plus an impermeable apron. Choose lightweight clothing to prevent heat stress. Take other precautions, such as switching to half-face respirators, or the use of drinking tubes in full face respirators, to avoid the effects of heat stress.
3. *Head protection:* Wear disposable head cover or hair cover to keep hair clean.
4. *Foot protection:* Wear disposal shoe covers or rubber or polyethylene boots that can be reused after disinfection.
5. *Eye protection:* Safety goggles worn should be non-vented or, at a minimum, indirectly vented (or a respirator with a full face-piece, hood, helmet, or loose-fitting face-piece). For employees who wear prescription lenses, make sure goggles can be fitted over regular glasses without compromising eye or respiratory protection; or alternatively use lens inserts in the goggles or use goggles with the correction built-in.
6. *Respiratory protection:* Wear National Institute for Occupational Safety and Health (NIOSH)-approved disposable respirator (N-95, N-99, or N-100) or NIOSH-approved reusable particulate respirator. Wear whenever exposure may occur to airborne infectious materials. Make sure that eye protection does not interfere with the face-piece seal of the respirator. The wearer should conduct a seal check each time he/she dons a respirator. For farms using oils as dust-suppressants, use minimum R-95 or P-95 disposable respirators.
    a. To be effective, tight-fitting respirators must have a proper sealing surface on the wearer's face. Items that interfere with the proper seal of a respirator include: facial hair, skull cap, facial features such as wrinkles, absence of one or both dentures,

Appropriate personal protective equipment should be worn when working with diseased animals.

Loose-fitting powered air-purifying respirator with a helmet.

weight gain or loss since a previous fit-testing (may necessitate a new fit-testing), glasses, skin conditions which render shaving difficult, or allergies (such as to rubber; silicone respirators are available as an alternative).

b. For employees who are unable to wear a disposable particulate respirator because of facial hair or other fit limitations, they can wear a loose-fitting helmeted or hooded powered air-purifying respirator (PAPR) with high-efficiency particulate air (HEPA) filters. The face-piece provides eye and mucous membrane protection as well as respiratory protection. Occupational Safety and Health Administration (OSHA) requires that respirators must be used in the context of a complete respiratory protection program as per 29 CFR 1910.134; this includes training, fit-testing, and user seal checks to ensure appropriate respirator selection and use.

Pathogen Reduction

The hygienic quality of compost is generally measured by complying with US EPA part 503 processes to significantly reduce pathogens (PSRP) and/or processes to further reduce pathogens (PFRP) which regulate sewage sludge compost. For PSRP, using either in-vessel, aerated static pile or windrow composting methods, the temperature should be 104°F (40°C) or higher and remain at that level for 5 days. Four hours of the 5 days should show temperatures that exceed 131°F (55°C). To further reduce pathogens, the temperature is maintained at 131°F (55°C) or higher for 3 days for in-vessel and aerated static pile composting and 15 days or longer, with 5 turnings during that period, for windrows. Meeting these requirements, along with testing for either fecal coliforms or *Salmonella* spp. gives sewage sludge compost Class B (low public contact use) or Class A (unrestricted use) classification, respectively by the EPA. For health and safety reasons and in the interest of being cautious, it is recommended that compost produced from mortalities be used in low public contact settings regardless of whether or not it meets the Class A requirements.

Many researchers have shown that composting inactivates pathogens such as E. coli O157:H7 (Xu et al., 2009), and Salmonella (Collar et al., 2009), and viruses such as Newcastle disease (ND) virus (Benson et al., 2008) Avian Influenza (AI) virus (Senne et al., 1994; Flory and Peer, 2009), and adenovirus that causes egg drop syndrome-76 (Senne et al., 1994) and have attributed this inactivation to high temperatures. However, using real-time reverse transcriptase polymerase chain reaction (PCR) Guan et al. (2009), provided evidence that in addition to temperature, microbial activity during composting contributed to the rapid killing of AI and ND viruses and to the degradation of their viral RNA. In the aforementioned Glanville et al. (2013) study where Class A temperatures were not consistently met, survival times of vaccine strains of avian encephalomyelitis (AE) and ND virus in cornstalk and straw/manure tests were similar to those in test units constructed with silage during summer trials, but noticeably longer during winter trials. Pathogen reduction in road-killed deer composting piles took up to 12 months in piles where the highest temperatures reached were 104°F (40°C) compared to 3 months in piles reaching 131°F (55°C), suggesting that the athermic properties of composting (e.g. pH, microbial and enzymatic activity) are also at work in pathogen and disease control (Schwarz, et al., 2010).

Spore-formers, hardy viruses, and other disease-causing organisms (e.g., prions) that are known to be resistant to heat, and are more resistant to other environmental stresses have also been studied in the composting environment. Viruses such as picornavirus (responsible for Foot and Mouth disease - FMD), Infectious Bursal Disease virus (IBDV), and pseudorabies virus (PRV - responsible for Aujeszky's disease) pass into the environment from clinically ill or carrier hosts, and although they do not replicate outside living animals or people, they are resistant to many environmental stresses and thus can be maintained and transported to susceptible hosts. Guan et al. (2010b), investigated the inactivation and degradation of FMD virus during composting of infected pig carcasses as measured by virus isolation in tissue culture and by PCR. FMD was inactivated in specimens in compost by day 10 and the viral RNA was degraded in skin and internal organ tissues by day 21. In another study, by day 7 in compost, IBDV had been inactivated in specimens that had been inoculated with virus and was inactivated in tissues taken from infected chickens by day 14 (Guan et al., 2010a). Survival of PRV was studied by Garcia-Siera et al. (2001). Pigs infected with PRV were composted for 35 days. Tissue samples collected on days 7 and 14 were culture negative for PRV. Some bacteria have the ability to enter a dormant or viable non-culturable state but later revert to a vegetative form, such as *Mycobacterium avium* subspecies paratuberculosis (MAP). MAP-infected dairy manure was seeded in the abdominal cavities of road-killed deer and removed at weeks 0, 3, 6, 0, 12, and 36 for analysis (Schwarz et al., 2010). MAP levels decreased immediately from 4.5 log10 cfu/g at week 0 to 0.1 to 0.2 log10 cfu/g through week 12. Each week, eight out of nine samples analyzed were culture negative. However, at week 36, 6 of the samples had values of around 2 log10 cfu/g (actual counts of 1 to 30 colonies) and one of the samples had colonies that were too numerous to count (>3,000). The duration of high temperatures achieved during the thermophilic process was unfavorable for bacterium survival, but it is possible that when conditions are more favorable, MAP may revert to its vegetative form. Therefore, care must be taken in the use of the compost to ensure ruminants are not exposed to these bacteria.

Reuter et al. (2012) has performed compost studies that investigate microbial communities linked to biodegradation. *Bacillus* spp. spores (related to anthrax outbreaks) carry exceptional resistance to heat, but spore survival times were magnitudes lower when exposed to wet-heat in compost as compared to dry-heat. Their data revealed that under composting conditions, a million-fold inactivation of *Bacillus* spores occurred and residual spores within compost bio-containment are unlikely to remain at an infectious concentration due to dilution. In addition, the use of molecular biology and microbiological assays revealed biodegradation of specified risk materials and a wide range of pathogens in combination with physiochemical compost conditions. Hongsheng et al. (2007) investigated whether the abnormal prion protein (PrPSc) in tissues from sheep with scrapie would be destroyed by composting. Before composting, PrPSc was detected in all the tissues by Western blotting, but not detected in the first experiment after composting. It was detected in the second experiment but analysis showed there were more diverse microbes involved in experiment 1 than in experiment 2. It was suggested that the greater dominance of thermophilic microbes in experiment 1 may have value as a means for degrading PrPSc in carcasses and other wastes. In another experiment using PrPSc over 28 days in laboratory-scale composters, Xu et al. (2013) showed that prior to composting, PrPSc was detectable in manure with 1 to 2 log10 sensitivity, but was not observable after 14 or 28 days of composting. The authors state that this may have been due to either biological degradation of PrPSc or the formation of complexes with compost components that precluded its detection.

However, as the effect of composting on prion survival is unknown, it is best to keep potentially-infected carcasses out of compost piles where there is any intention to use the resulting compost. Until research demonstrates that composting can destroy prions, it should be presumed that compost made from infected material also carries the prions. In cases where animals are suspected of, or confirmed with prion diseases, it is recommended that composters work with state and federal veterinarians. Composting might be completed in a contained area to reduce volume and moisture. Then the resulting residuals, chips, and bones could be burned in a high temperature incinerator to destroy the prion. Burning whole animals at high temperatures is energy intensive and it is difficult to achieve high temperatures throughout large carcasses.

Disease-causing organisms represent only a very small fraction of the microbial community in compost piles, and they are effectively destroyed by the high temperatures and antagonistic environment of the compost pile. Other biological health concerns include potential exposures to bacteria, endotoxins, fungi (molds and yeast), parasites (protozoa, protistans), worm cysts, and viruses. While all of these biological agents exist in the environment, they are likely to be present in higher concentrations at composting sites, and also farms, due to nature of the feedstocks and the fact that composting fosters biological decomposition. Brown (2006) recommends that despite the capabilities of the composting process and methods, potential biological hazards deserve respect. Precautions should be taken that include minimizing exposure, sensible hygiene practices, personal protective equipment and health monitoring. Immunization recommendations for compost workers are not different from the general population. Due to the potential for cuts and puncture wounds, compost workers should consider keeping their tetanus vaccination up-to-date.

Leachate and Veterinary Drugs

Biological issues are not the only concern in mortality composting. Concentration of nutrients in leachate from composting, and the fate of veterinary pharmaceuticals from euthanatized animals are a concern for the environment, as well as in the use of the compost product. Hutchinson, et al. (2012) found that carcass compost piles develop an identifiable structure with zones that can be distinguished based on color, texture, moisture, and chemical composition. This structure appears to help minimize nitrogen losses by intercepting both soluble nitrogen in fluids and gaseous ammonia and concentrating them in the organic material. Compost leachate is variable in terms of its chemistry and is influenced by feedstock, process, maturity, cover, and weather. Generally, the higher the carbon to nitrogen ratio, the less leachate will be formed. Woodchips as a base will absorb leachate, and lower turning frequency will decrease leachate production. Donaldson et al. (2013) demonstrated this in a study that analyzed leachate constituents in deer mortality static windrow composting. They concluded that soil filtration of leachate was effective in reducing concentrations of ammonia, chloride, and total organic carbon, and that the low volume of leachate (i.e., 2% of the precipitation that fell on windrows) results in nominal losses of nitrate and other contaminants. Schwarz, et al. (2013) also showed that very little leachate is produced during carcass composting as approximately 1.7% of total fluids from a horse carcass were collected, with the rest being absorbed by the woodchips in the compost pile. However, if composting is performed using material that is too dense and not able to reach temperature, more leachate is generated and can become problematic in terms of nutrient loading as well as resulting in higher pathogen levels in the end product (Bonhotal and Schwarz, 2009).

The fate of sodium pentobarbital (euthanasia drug) and phenylbutazone, a non-steroidal anti-inflammatory drug (NSAID) has been studied by Schwarz, et al. (2013). The finished compost in that study contained either no or very low concentrations of both NSAIDs and barbiturates. In contrast, Payne et al. (2012) found sodium pentobarbital persistence up to 129 days in compost piles with no clear trend of reduction. However, when managed properly, composting will deter domestic and wild animals from scavenging on treated carcasses while they contain the highest drug concentrations.

Summary

Mortality composting has been proven effective in deactivating pathogens, limits the risk of groundwater and air pollution contamination, and on-site composting reduces the potential for farm to farm disease transmission as well as decreases transportation costs and tipping fees associated with off-site disposal. There is also the added benefit of producing a usable product. As with any farm operation health and safety issues exist in mortality composting. Proper training of workers is the best means to reduce those health and safety issues.

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