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Perspectives in Alkaline Hydrolysis

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The commercialization of alkaline hydrolysis technology used in tissue digester systems has led to many new innovations in the process and equipment design — some of which have led consumers to many perceptions and misconceptions regarding the process due to the changing technology.

Making sense of a myriad of new information concerning advances and claims in alkaline hydrolysis technology is an overwhelming task for even the most educated consumer, but a necessary one for anyone considering the science. Features such as "wet" or "dry" processes and "prion" or "non-prion" decontamination cycles require that anyone considering the technology have somewhat of a basic understanding of the process. Past issues regarding pH control, repeatability of the process, and biological oxygen demand (BOD), for example, have clouded the perception of alkaline hydrolysis and have made it even more difficult for the consumer to make educated decisions.

In analyzing all this new information, the main consideration and understanding should be the intent of the process and equipment: ensuring efficacy of the process.

Acquiring a basic knowledge will lead to a better understanding of the methods used to achieve a wet or dry result and its relationship to energy consumption and, since these factors are all inter-related, to cost.

Efficacy

In vivo infectivity studies have validated the effectiveness of the alkaline hydrolysis process for the inactivation of prioninfectivity.[1] These studies established baseline parameters for the inactivation of prion infectivity and were adopted by the USDA, European Union, and Canadian Food Inspection Agencies. Potassium hydroxide (KOH) or sodium hydroxide (NaOH) in an amount sufficient to hydrolyze infected animal tissues was used to achieve prion inactivation. Extending this knowledge to whole carcasses, sufficient KOHis needed to allow for its consumption by carcass components such as fat and protein materials. Using a KOH solution of 1 molar is the current accepted working concentration for use in the complete digestion of typical animal carcasses.

In addition to having the correct chemical ratios, water (H_2O) is also a key part of the basic hydrolysis reaction. H_2O is the key component that breaks chemical bonds by the insertion of its structure between the bonds of the atoms. If there is an inadequate amount of H_2O during the hydrolysis process, complete digestion will not occur, leaving behind undigested proteins and possibly viable prions. This concept has been very misunderstood and needs to be made clear—sufficient water is key to the alkaline hydrolysis process. Using less caustic amounts or smaller water volumes in any alkaline hydrolysis process would not meet the recommendations and guidelines of the USDA, European Union, and Canadian Food Inspection Agencies.

The resultant process and its accompanied caustic ratios, based on molar equivalency of the processed tissue, have been reviewed, accepted, and recommended by the USDA, European Union, and Canadian Food Inspection Agency in industry reports published by these agencies.[2,3,4] "Approved alkaline hydrolysis processes require processing infectious material in a hydroxide solution calculated on amass per mass basis equal or greater than 9% of the infectious material, which corresponds to 15% sodium hydroxide solution (NaOH) or 19.3% potassium hydroxide solution (KOH)"[3]of the total processed tissue weight.

Energy Consumption

The amount of energy consumed by the tissue digester system is a function of efficacy level desired and whether a "wet" or "dry" process has been selected. The selection of wet or dry output will make a dramatic difference in the amount of energy consumed due to the extended cycle time and heat energy required to evaporate the excess water. The amount of heat energy required to heat the amount of caustic, water, and digester contents to the decontamination temperature of 300°F is based on the equation:

$$Q = mc\,(T_2 - T_1)$$

Where

Q = Heat Energy required to raise a specific mass from the initial temperature T_1 to the final temperature T_2

m = mass of water + caustic + anatomic waste

c = specific heat of the mass

In order to achieve a dry result, a wet process result must first be achieved to effectively reproduce the conditions necessary to achieve complete digestion. Upon completion of the wet result, the effluent is dehydrated by heating the effluent in order to remove the moisture so that it turns into a thick molasses-type solution. Since the dry process must first replicate the wet process, in addition to utilizing energy to evaporate off moisture to achieve the ending result, the dry process will always consume more energy resulting in higher energy costs (see Table 1).

Table 1: Energy Consumption

	Wet Process at 300°F	Dry Process at 300°F
Exposure Time Duration	6 Hours	9 Hours
Heat Energy required to attain 300°F	683,100 BTUs	683,100 BTUs
Heat Energy to maintain 300°F for the exposure time	66,861 BTUs	98,015 BTUs
Heat Energy for dehydration of effluent (vaporization)	0	679,000 BTUs
Total Energy Required	749,961 BTUs	1,460,115 BTUs

*Assumptions based on equivalent molar weights and water volume for a 1,000 lb capacity tissue digester as per USDA & EU Directives. Heat Energy=Q=mc $(T_2 - T_1)$

Wet versus Dry Results

The dry process resultant is a method that was devised to eliminate the issue of high BOD levels being discharged to drain in the wet process which, in the past,may have been an issue with local sewage treatment authorities. However, logistics of the dry process eliminate the automated, sanitary, contained, closed loop design associated with most bio-hazardous waste decontamination systems. Therefore inherent design features of the dry process limit the application since it is open to the atmospheric conditions of the surrounding space and may cause re-contamination of the processed material or facility in such areas as BSL-3 applications.

Another hurdle to overcome with the dry process is consistency. Since the exact moisture and fat content of any given carcass is unknown, the amount of evaporation time cannot be accurately determined by a set formula. This inconsistency leads to over-drying or under-drying of the effluent which leads to high levels of operator interface with the equipment. The large mass of dehydrated material must be drained at a temperature that will allow for the dehydrated mass to flow so that the processing vessel may be completely emptied. This high temperature mass poses not only a physical hazard to the operator but will also put off a very offensive odor causing the container to be stored outside. With the need to have the process effluent stored outside, additional design considerations must be made for hosting and moving potentially large containers in and out of the facility.

As an alternative to the dry process and a solution to high BOD levels of discharged effluent, recent advances in filtration of the wet process resultant have produced systems which lower BOD by as much as 95% to levels less than 5,000mg/L and suitable for acceptance by any sewage treatment authority. Other advances in the wet process allow high pH levels to be automatically adjusted prior to discharge to drain via injection of gaseous or liquefied CO_2 to lower the pH value. Generally, if proper education and information is provided to the waste water treatment authorities to make them aware of the composition of the wet process, an agreement on release rates, times, or even a waiver can be agreed upon by the involved parties.

Cost of Operation

For anyone considering alkaline hydrolysis as part of their bio-hazardous waste treatment facility plan,many factors must be considered in the justification of the equipment. The cost of capital equipment and the associated yearly cost of operation versus incineration or third party bio-hazardous waste removal must be evaluated independently for each application and the associated amount of waste to be processed on-site.

Factors in the equipment selection and justification include initial equipment costs, utility costs, cost of the caustic chemical (KOHor NaOH), and landfill charges. Landfill charges will be realized from any remaining sterilized waste ruminants (bones in the wet process) or from filled dumpsters containing the dehydrated effluent (in the dry process).

For the wet process, the sterilized effluent may be discharged to drain in locations where BOD issues have been addressed by either lowering of the BOD level or through release waivers. For tissue digesters with BOD Reduction systems, waste from the digester's filtration system will produce minimal amounts of landfill waste whose volume is dependent on the size of the tissue digester. For a typical 1,000 lb capacity tissue digester, the wet process produces approximately 10 lb of landfill waste.

In contrast, the amount of landfill waste remaining in the dumpsters in the dry process for the same 1,000 lb capacity tissue digester is approximately 500 lb. The disposal charges for this type of landfill include cost per ton in addition to pick-up costs for the dumpster. Typical costs for dumpster pickup are $30.00 per ton and $200.00 per dumpster pickup which, based on a yearly requirement, can far outweigh the cost of the wet process and inhibit the justification of the process due to the cost of waste disposal as shown in Table 2.

For critical applications such as in BSL-3 and BSL-4 environments, efficacy of infectious waste is the determining factor in the application of alkaline hydrolysis since considerations for biocontainment and safety become the top priority in lieu of waste disposal costs. Having the capability to decontaminate on-site provides a necessary component to safely operating in high containment applications. On-site disposal also eliminates transporting the infectious waste off-site at costs that are much higher than standard landfill disposal fees.

Table 2: 1,000 Lb Tissue Digester - Cost of Operation for 200 Cycles

Requirement	Wet Process		Dry Process	
		Costs $$		Cost $$
Steam Utility[a]	750 lb/cycle	$2,637.18	1,509 lb/cycle	$5,304.92
Chemical[b] (KOH or NaOH)	200 lb/cycle	$15,600.00	200 lb/cycle	$15,600.00
Water Utility[c]	1500 lb/cycle =180 gal/cycle	$191.92	1500 lb/cycle = 180 gal/cycle	$191.92
Electrical Power[c]	100 W	$218.76	155W	$339.09
Landfill disposal costs[d]	10 lb/cycle	$230.00	500 lb/ dumpster/cycle	$41,500.00
Total Cost of Operation per 200 Cycles		$18,877.86		$62,935.93
Total Cost per Lb.		$0.094		$0.315

a. Steam requirement based on total BTUs required for process listed in Table 1
Steam cost = $.017 per lb steam
b. Chemical quantity listed is based on recommendations of USDA and EU Directive for efficacy.
c. Water & Power requirements correspond to item 2. Water cost = $.0053 per gallon.
Electrical power cost = $.05 per KWh
d. Landfill disposal costs based on disposal costs of $30/ton plus $200 for each dumpster pickup. For the dry process, this amount is 500 lb per cycle per dumpster.
For the wet process, the amount is 10 lb.

Sustainable Energy

Recent advances in post-treatment processing of the sterile effluent from the alkaline hydrolysis process can provide sustainable energy sources in the form of fertilizer, bio-diesel fuels, and bio-gas from large-scale tissue digester operations where large volumes of material are processed on a weekly basis. In the generation of bio-diesel, the amount of fuel realized from each digester cycle ranges based on the type of anatomic tissue processed, which is dependent on the fat content within the waste. In the generation of bio-gas,methane gas can be captured from concentrated effluent discharged to an anaerobic digester.

Conclusion

As in other technologies that have been developed, the commercialization of alkaline hydrolysis has transformed what was once a science experiment into a now viable method of bio-hazardous wasted contamination through improvements to the process and through post-treatment processing of the effluent into an acceptable end product. As the cost of third party bio-hazardous waste removal continues to rise, the application of alkaline hydrolysis will continue to grow as a viable and cost effective method of bio-hazardous waste disposal. Today, the period for return on investment ranges from two to three years depending on the amount of waste processed. Cost savings can be further enhanced by the generation of sustainable energy sources in lowering the yearly cost of operation in large scale processing applications.

As applications of alkaline hydrolysis grow more critical in nature, a basic knowledge and understanding of the process, rules, and regulations is required so that informed decisions can be made from the myriad of claims and information available on the topic.

References

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