**Safer Alternatives To Traditional Cadaver Embalming**

**Abstract:**

The most common component of embalming fluid is formaldehyde, as it is extremely efficient at preserving tissue; unfortunately, formaldehyde is an extremely hazardous, carcinogenic chemical. Three alternative methods of embalming were investigated based on each method’s associated health hazards and quality of anatomical preservation. It was found that while the Thiel method of embalming produces the highest quality specimen, the nitrite pickling salt method was the most effective alternative to formaldehyde embalming, producing a quality specimen without compromising safety.

**Background and Significance:**

Embalming is the act of preserving a cadaver through the use of natural or artificial materials, with the intention of delaying decomposition (“Embalming,” n.d.). The act of preserving the dead has been around for thousands of years, with the earliest known form of artificial preservation having been performed by members of the Chinchorro culture around 6000-5000 BC (Marquet et al., 2012).

The most notorious embalmers in history, the Egyptians, were very particular about their mortuary practices. This is because the ancient Egyptians believed in the afterlife, and that the preparation of a body was crucial in determining the survival of the deceased individual in the afterlife (“Treatment of the Dead - Animals and Belief – Ancient Egypt,” n.d.). The ancient Egyptians’ method of embalming is still shrouded in mystery, as actual procedure of embalming that the Egyptians undertook was never written down (Brier & Wade, 2001). By investigating the remains of Egyptian mummies, it is immediately clear the mode of preservation used by the Egyptians was dehydration. Dehydrating the body prevents bacteria from taking root, as bacteria require ample moisture to survive (“Mumab,” n.d.). The ancient Egyptians utilized a material called natron, a mixture of sodium bicarbonate, sodium chloride, and sodium carbonate decahydrate, to desiccate the body (“Mumab,” n.d.). Natron is a common occurrence on the banks of Egypt’s delta, as the waters have an extremely high level of salinity, allowing large deposits to form on the banks (“Mumab,” n.d.).

Only within the last few hundred years has formaldehyde been used for the fixation of tissues (Fox, Johnson, Whiting, & Roller, 1985). Formaldehyde is the most commonly used chemical fixative, as it interacts with a wide variety of molecular targets (“Fixation Strategies and Formulations,” n.d.). This toxic chemical fixes tissues by forming methylene bridges between primary amines located on proteins and nucleic acids, denaturing the proteins, making the now fixed proteins indigestible by bacteria (“Fixation Strategies and Formulations,” n.d.). In addition to this fixative property, formaldehyde is a superb germicide, fungicide, and disinfectant, removing the need to use multiple chemicals in the preparation of a cadaver (“Formaldehyde and Cancer Risk,” n.d.).

Formaldehyde is not restricted to the halls of an anatomy lab or embalming room, however; industrially, it is commonly used in the manufacturing of various pressed-wood products, insulations, and cleaning products, which are commonly used in households (“Formaldehyde and Cancer Risk,” n.d.). The workers most often exposed to formaldehyde or formaldehyde containing-products are lab technicians, health care students and professionals, mortuary workers and industrial workers working around formaldehyde resins.

The recommended exposure limits for occupational exposure to formaldehyde are defined as 0.016 parts per million (ppm) time-weighted average (TWA), which is the average exposure over an 8-hour period of time, and a 15-minute short-term exposure limit (STEL) of 0.1 ppm (“CDC - Immediately Dangerous to Life or Health Concentrations (IDLH): Formaldehyde - NIOSH Publications and Products,” n.d.). The permissible exposure limits are 2 ppm STEL and 0.75 ppm TWA (“CDC - Immediately Dangerous to Life or Health Concentrations (IDLH): Formaldehyde - NIOSH Publications and Products,” n.d.). The average TWA of formaldehyde-exposed workers is 0.45 ppm, with less than 3% of the workers exposed to more than 2 ppm TWA (“Formaldehyde,” n.d.).

As a result of environmental pollution, formaldehyde is found in the ambient environment at levels less than 0.03 ppm. Formaldehyde levels exceeding 0.1 ppm can begin to cause adverse effects such as burning mucosal membranes, coughing, and nausea. Several studies have exposed formaldehyde as being a carcinogen, increasing the exposed person’s risk of developing a form of leukemia, called myeloid leukemia, as well as cancer of the nasal sinuses (“Formaldehyde and Cancer Risk,” n.d.; Arican et al., 2009; Holness & Nethercott, 1989; Hauptmann et al., 2009; Jakab et al., 2010; Zhang et al., 2010). It was also found that workers exposed to formaldehyde over a long period of time have an increased rate of chromosomal aberrations and apoptosis in peripheral blood lymphocytes (Jakab et al., 2010; Li et al., 2013). Long-term formaldehyde exposure has recently been questioned as a possible cause of amyotrophic lateral sclerosis (Roberts, Johnson, Cudkowicz, Eum, & Weisskopf, 2015).

In the civilized society that we inhabit, it is unacceptable to knowingly allow the use of a chemical that could very well be the cause of premature deaths of morticians and health care professionals. Not only is it immoral, it could also be detrimental to the mortuary and medical job market. Knowledge of the formaldehyde related hazards would reduce the number of individuals going into these fields, for self-preserving reasons.

In this review, the practicality of multiple methods of embalming will be compared; comparisons will be made of health risks associated with materials and the anatomical quality of the embalmed body for each method. The embalming methods that will be contrasted include the standard formaldehyde method, Thiel method, nitrite pickling salt method, and ethanol-glycerin method (Hayashi et al., 2014; Hammer et al., 2015; Janczyk et al., 2011; W. Thiel, 1992; 2002).

**Current Issue**

Since formaldehyde-embalmed bodies pose a risk to those interacting with it, other methods have been developed over the years, though none have been able to replace formaldehyde completely. Methods such as the Thiel method of embalming and ethanol-glycerin method are known as low-formaldehyde methods of embalming, as they use a lesser amount of formaldehyde than what is used in standard formaldehyde embalming (Hammer et al., 2015; W. Thiel, 1992; 2002). However, even in small quantities the risks associated with formaldehyde can remain. In small quantities, formaldehyde is still extremely potent, causing eye, respiratory and mucosal membrane irritation (“CDC - Immediately Dangerous to Life or Health Concentrations (IDLH): Formaldehyde - NIOSH Publications and Products,” n.d.). In response, formaldehyde-free methods of embalming have been developed. A single notable example of formaldehyde-free methods includes the nitrite pickling salt method.

In order for an embalming method to be effective, it must successfully preserve the tissues in an anatomically accurate manner, as well as in a safe manner. In other words, the fluid must destroy pathogens and inhibit the growth of new pathogens. In addition, the fluid itself must not pose a health hazard to those interacting with the fluid or body. A secondary necessity is that of practicality. If a method is extremely space and time consuming, it is not entirely practical, thus reducing its feasibility for budget and space-crunched science departments.

The above needs are only applicable for anatomical embalming. Generally for anatomical embalming, a body is embalmed through an arterial injection of the formalin embalming fluid; the focus of the embalming is not directed towards cosmetic appearance. For mortuary embalming, the process can be a little bit more convoluted, and extremely more cosmetically focused. The funerary embalming process begins with an antibiotic wash of the body and a muscular massage in order to relax the muscles from rigor mortis (“The Embalming Process (Explicit),” n.d.). After suturing the mouth closed, the blood is removed from the body through arterial embalming, which involves injection of embalming fluid into an artery and drained through a vein. The fluid used in funerary embalming contains other chemicals besides formaldehyde, such as dyes to simulate a life-like coloration (“The Embalming Process (Explicit),” n.d.). A trocar is then inserted into the body cavity to drain fluid and gas from the organs, which is then replaced by embalming fluid that, again, contains a mixture of chemicals beyond just formaldehyde in order to simulate a life-like appearance of the body (“The Embalming Process (Explicit),” n.d.).

A formalin solution can contain a wide variety of chemicals, but the chemicals that generally remain constant in the mixtures are formaldehyde, phenol, glycerine and water (Hayashi et al., 2014). As a result, the formalin mixture that was looked at contained a 20% formaldehyde solution, phenol, glycerine, and water (Hayashi et al., 2014).

The Thiel method of embalming requires multiple steps, and the mixtures used can be seen on Table 1. The first step involves an arterial injection of the Infusion/Visceral solution (Table 1) through the external iliac artery and the popliteal artery, followed by the injection of the same solution intra-thecally, intra-tracheally, and intra-rectally (Hammer et al., 2012; W. Thiel, 1992; 2002). After injection, the cadavers are submerged in the storage solution (See Table 1).

The nitrite pickling salt method has only one known experimental use, and it was utilized on twenty dog cadavers. The embalming mixture, referred to as the fixation-preservation salt solution (FPS), contained 23% nitrite pickling salt, 30% ethanol, 20% Pluriol® 400, 26.9% tap water and 0.1% oregano oil (Janczyk, Weigner, Luebke-Becker, Kaessmeyer, & Plendl, 2011). The FPS mixture was injected arterially, through the common carotid, in a quantity of 5-10L; the amount injected into each dog varied based on body mass (Janczyk et al., 2011). The bodies were then covered in FPS soaked fabrics and stored for 3-7 days at 4-6°C before being transferred into tanks containing FPS and stored, again, at 4-6°C (Janczyk et al., 2011). Ten of the cadavers were opened along the *linea alba* before being placed in the tank of FPS in order to determine if having an open body cavity influences the degree of preservation (Janczyk et al., 2011). This experiment ran into a problem in the beginning as it originally contained an antioxidant, ascorbic acid (Janczyk et al., 2011). After initial testing, it was found that the ascorbic acid caused corrosion to the stainless-steel equipment, as well as discoloration to the laboratory’s terrazzo floor (Janczyk et al., 2011).

The ethanol-glycerin method of embalming utilized an embalming mixture composed of 94.5% ethanol, 4.9% glycerin, and 0.6% thymol (Hammer et al., 2015). This mixture composition is subject to change, based on the physical constitution of the body being embalmed (Hammer et al., 2015). The mixture is injected arterially over an average period of 36 hours (Hammer et al., 2015). Once complete, the body is submersed in the solution for four weeks before being stored at 3-5°C in cotton cloths and polyethylene foil (Hammer et al., 2015). In order to preserve the central nervous system, a subdural injection of a 1.3% water-diluted formaldehyde (by volume) mixture, or by removal of and submersion of the central nervous system in the same formaldehyde mixture (Hammer et al., 2015).

When it comes to realism, the most promising method is the Thiel method of embalming. This method produces extremely realistic cadavers to the point of some undergraduates experiencing psychological distress (Balta, Lamb, & Soames, 2015). Anatomically, the only complaints that can be made concerning the result of this embalming procedure is that this method causes the elastic cartilage in the body to dissolve (Hammer et al., 2015). One of the most impressive results of this method is the life-like color and flexibility of the cadaver. The muscles retain a pinkish-red coloration, and the soft-tissues remain soft (Hammer et al., 2015). A few of the chemicals used in the Thiel method of embalming have antibiotic properties. Morpholine has fungicidal properties, ethanol has disinfectant and bactericidal properties and, to reiterate, formaldehyde is a superb fungicide, antiseptic, disinfectant and tissue fixative (“ethanol | C2H6O - PubChem,” n.d., “formaldehyde | CH2O - PubChem,” n.d., “Formaldehyde and Cancer Risk,” n.d., “Morpholine (EHC 179, 1996),” n.d.).

The quality of Thiel embalming comes at a cost, as it requires a greater amount of space and time to perform, in addition to costing nearly twelve times that of regular formaldehyde embalming (Hammer et al., 2015). The ethanol-glycerin method of embalming is also more expensive than formaldehyde embalming, costing a lesser twice as much as formaldehyde embalming (Hammer et al., 2015).

The nitrite pickling salt method was successful in preserving multiple dog cadavers for a period of time longer than a year, even though the solution did not contain any formaldehyde. However, a problem that this method encountered is that the cadavers must have their abdominal cavities opened during the embalming process if their internal organs are to be adequately preserved. The antibiotic effects of the nitrite pickling salt method are great. The effects were amplified by the addition of a maintenance task, which involved the wiping down of the body with an ethanol-glycols solution after each handling. 24 weeks, post embalming, before the additional method of maintenance was added, the nitrite pickling salt embalmed cadavers harbored various species of bacteria, including species of *Clostridium* and *Enterococcus* (Janczyk et al., 2011). After the maintenance method was started, the prevalence of bacterial species on the cadaver dropped drastically, with the only bacterial populations being found within the colon, even after 30 weeks (Janczyk et al., 2011). These results can be seen in Table 3. By comparison, the cadavers embalmed by standard formalin method (6% and 3% formaldehyde solutions) had to be removed from the dissection course, as astronomical numbers of mold had grown after 24 weeks, post treatment. In addition, all samples embalmed with formaldehyde were dominated by two bacterial species in particular, *Trichoderma* sp and *Scopulariopsis* sp (Janczyk et al., 2011).

The ethanol-glycerin method, like the Thiel method, is a low-formaldehyde method of embalming. For the majority of the embalming procedure, no formaldehyde is used. The only reason formaldehyde is eventually used is to preserve the central nervous system (Hammer et al., 2015). The ethanol-glycerin method produced results similar to formaldehyde embalming in the respect that the tissues were rigid, or indurated (Hammer et al., 2015).

**Health Effects**

The chemicals used in formaldehyde embalming are all labeled as chemicals that induce local inflammation when introduced to normal living tissue, otherwise known as an irritant (“The MSDS HyperGlossary: Irritant,” n.d.). Formaldehyde is, according to its Material Safety Data Sheet (MSDS), also labeled as being fatally toxic, causing gastrointestinal irritation, corrosion, ulceration, and possible failure (“Formaldehyde 37% solution MSDS,” 2013). Phenol is also labeled as a toxic and corrosive substance, causing gastrointestinal, dermal and respiratory sensitization and corrosion post-exposure. Due to its ability to be absorbed through the skin easily, it can cause serious problems such as convulsions and death after being absorbed through the skin (“CDC - PHENOL - International Chemical Safety Cards - NIOSH,” n.d.). Glycerin is only labeled as an irritant (“Glycerin MSDS,” 2013).

Thiel embalming utilizes a wide selection of hazardous chemicals including formaldehyde, propylene glycol, and 4-chloro-3-methylphenol. Propylene glycol, not to be confused with ethylene glycol, is not feasibly toxic, as it requires a large amount of the chemical to produce a toxic effect (“ATSDR - ToxFAQsTM,” n.d.). As a result, it is non-toxic, but it is a mutagenic and irritating sensitizer (“Propylene Glycol MSDS,” 2013). 4-choro-3-methylphenol is recognized as a highly toxic and corrosive irritant, with the ability to sensitize (“4-Chloro-3-Methylphenol MSDS,” n.d.). Sodium sulphite is a toxic, mutagenic and sensitizing irritant. It has been classified as a possible carcinogen, but not for humans, by the International Agency for Research on Cancer. The mutagenic effects of sodium sulphite include induction of mutation in mammalian somatic cells, as well as in bacteria and yeast. The toxicity of this chemical may target the peripheral and central nervous system (“Sodium Sulfite MSDS,” 2013).

The ethanol-glycerin method of embalming has much fewer chemicals. However, it still utilizes formaldehyde, as well as glycerin. Ethanol is also used, which is categorized as a toxic, mutagenic, irritating chemical. It has been proven to be a developmental toxin for humans, and is believed to be a possible reproductive toxin (“Ethyl Alcohol 200 Proof MSDS,” 2013). It is also toxic to the blood, liver, respiratory, epithelial, and central nervous system (“Ethyl Alcohol 200 Proof MSDS,” 2013). Thymol, the chemical used to improve the odor of the embalming fluid, is categorized as a toxic and irritating chemical. It is toxic to mucous membranes, and targets the kidneys, liver and central nervous system (“Thymol MSDS,” 2013).

The nitrite pickling salt method uses the same number of chemicals as the ethanol-glycerin method. The staple chemical, the sodium nitrite salts, are classified as toxic, mutagenic and irritating. Sodium nitrite is mutagenic to mammalian somatic cells, bacteria and yeast. It is classified as a possible reproductive toxin and teratogen for human. It is also classified as a possible cardiovascular, smooth muscle and blood toxin (“Sodium nitrite MSDS,” 2013). Pluriol is a form of detergent that is categorized as a nonhazardous chemical, though may be dermally irritating (“Polyethylene glycol 400 MSDS,” n.d.). Oregano oil was used just as thymol was used in the ethanol-glycerin experiment, to improve the smell of the embalming solution. Oregano oil is categorized as an irritant and a sensitizer, particularly to mucous membranes (“Oregano MSDS,” n.d.).

**Recommendations**

The Thiel method, which utilizes the largest number of hazardous chemicals, is also the most accurate method of embalming, producing an extremely life-like cadaver (Balta, Lamb, & Soames, 2015). The methods involved in embalming a body in the manner that Walter Thiel describes are monetarily, space, and time consuming, as well as labor intensive (W. Thiel, 1992; 2002). The ethanol-glycerin method, when used with formaldehyde, is slightly more dangerous than just formaldehyde embalming, as it also contains a mutagenic, ethanol (Table 2). The nitrite pickling salt method uses two known mutagens, ethanol and sodium nitrite, and no carcinogens or corrosive chemicals (Table 2). However, this method requires the abdominal cavity to be open during the body cavity embalming step (Janczyk et al., 2011). This could be seen as a problem for teaching external features, or natural positions of parts.

My recommendations include furthering research on the nitrite pickling salt method, as it does not contain as many hazardous to health chemicals as the other three methods listed previous. It is also successful in preserving tissue in without allowing the growth of microorganisms, when properly maintained (Janczyk et al., 2011).

In addition to this recommendation, it is also suggested that individuals limit any exposure time to formaldehyde, and formaldehyde embalmed bodies, if exposure to them is necessary. When working with or around formaldehyde, proper room ventilation is crucial.

Finally, if an extraordinarily realistic cadaver is needed and a body must be embalmed by the Thiel method, it is recommended that the embalmer, as well as those working around the body, wear a gastight suit to prevent exposure to the hazardous chemicals and vapors required for this method of embalming (W. Thiel, 1992; 2002).

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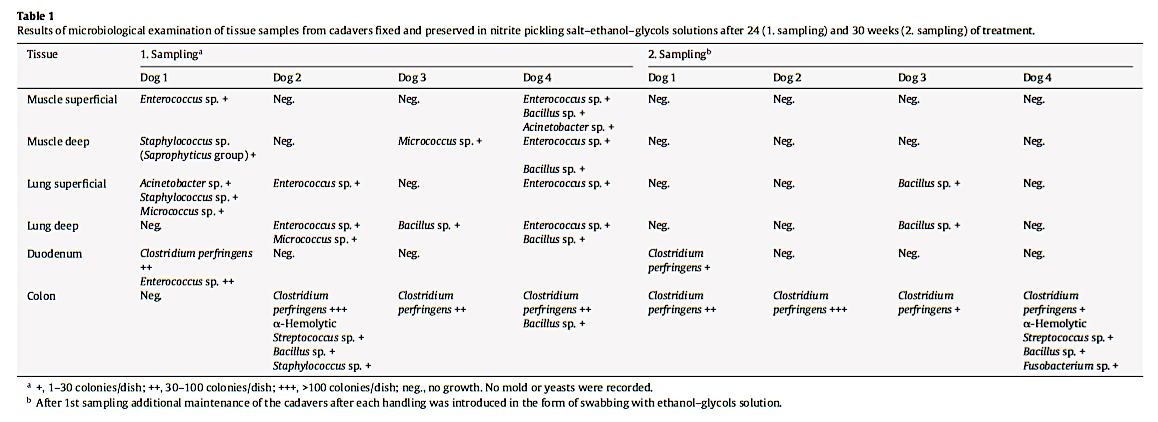
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**Table 1: Thiel’s solutions (Table adapted from Hayashi et al, 2014, with data originally from Thiel, 2002)**

|  |  |
| --- | --- |
| **Basic solution I**   * 100 ml Hot tap water * 3 g Boric acid * 30 ml Propylene-glycol * 20 g Ammonium nitrate * 5 g Potassium nitrate | **Basic solution II**   * 10 ml Propylene-glycol * 1 g 4-Chloro-3-Methylphenol |
| **Infusion/Visceral solution**   * 12,000 ml Basic solution I * 500 ml Basic solution II * 600 g Sodium sulphite * 450 ml Morpholine * 500 ml/1,000 ml Formaldehyde * 2,000 ml Ethanol | **Storage solution**   * 91 ml Hot tap water * 3 g Boric acid * 10 ml Propylene-glycol * 10 g Ammonium nitrate * 5 g Potassium nitrate * 9 ml Ethanol * 2 ml Formaldehyde * 7 g Sodium sulphite * 2 ml Basic solution II |

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| --- | --- | --- | --- | --- | --- | --- |
| **Table 2: Comparison of health hazards associated with different embalming methods**  Data obtained from Material Safety Data Sheets. Red signifies hazardous. | | | | | | |
| Material | Toxic | Mutagenic | Carcinogenic | Irritant | Corrosive | Sensitizer |
| Formaldehyde Method | | | | | | |
| Formaldehyde | Yes | Yes | Yes | Yes | Yes | Yes |
| Phenol | Yes | No | No | Yes | Yes | Yes |
| Glycerin | No | No | No | Yes | No | No |
| Thiel Method | | | | | | |
| Boric Acid | Yes | No | No | Yes | No | No |
| Propylene-glycol | No | Yes | No | Yes | No | Yes |
| Ammonium Nitrite | No | No | No | No | No | No |
| Potassium Nitrate | Yes | Yes | No | Yes | No | No |
| 4-Chloro-3-Methylphenol | Yes | No | No | Yes | Yes | Yes |
| Sodium Sulphite | Yes | Yes | No | Yes | No | Yes |
| Morpholine | Yes | No | No | Yes | Yes | No |
| Formaldehyde | Yes | Yes | Yes | Yes | Yes | Yes |
| Ethanol | Yes | Yes | No | Yes | No | No |
| Nitrite Pickling Salt Method | | | | | | |
| Sodium Nitrite | Yes | Yes | No | Yes | No | No |
| Ethanol | Yes | Yes | No | Yes | No | No |
| Pluriol | No | No | No | Yes | No | No |
| Oregano oil | No | No | No | Yes | No | Yes |
| Ethanol-Glycerin Method | | | | | | |
| Ethanol | Yes | Yes | No | Yes | No | No |
| Glycerin | No | No | No | Yes | No | No |
| Thymol | Yes | No | No | Yes | No | No |
| Formaldehyde | Yes | Yes | Yes | Yes | Yes | Yes |
|  | | | | | | |



**Table 3: (Taken from Janczyk, Weigner, Luebke-Becker, Kaessmeyer, & Plendl, 2011)**

Results of microbiological examination of tissue samples from cadavers fixed and preserved in nitrite pickling salt–ethanol–glycols solutions after 24 (1. sampling) and 30 weeks (2. sampling) of treatment