Investigation into the Use of Aquazol as an Adhesive on Archaeological Sites

by Vanessa Muros

Introduction

Archaeological conservators face many challenges when working in the field, none greater than the lack of availability of standard conservation materials and chemicals in many countries. In places where purchasing commonly used solvents is extremely difficult, conservators are faced with an even greater predicament in the lab when trying to make up resins for use as an adhesive or consolidant. For these types of situations, aqueous-based materials or those that are soluble in a wide range of solvents are often ideal.

The challenges described above are what led to the current investigations into the use of Aquazol (poly (2-ethyl-2-oxazoline) as an adhesive on archaeological sites. The characteristics, use and working properties of Aquazol have been described elsewhere (Arslanoglu 2003; Chiu, et al. 1986; Wolbers, et al. 1994) and will not be covered here in detail. What is of particular interest for use in the field however is Aquazol's solubility in a wide range of solvents, including water (Chiu, et al. 1986). In areas where solvents are difficult to obtain, Aquazol could be the resin of choice.

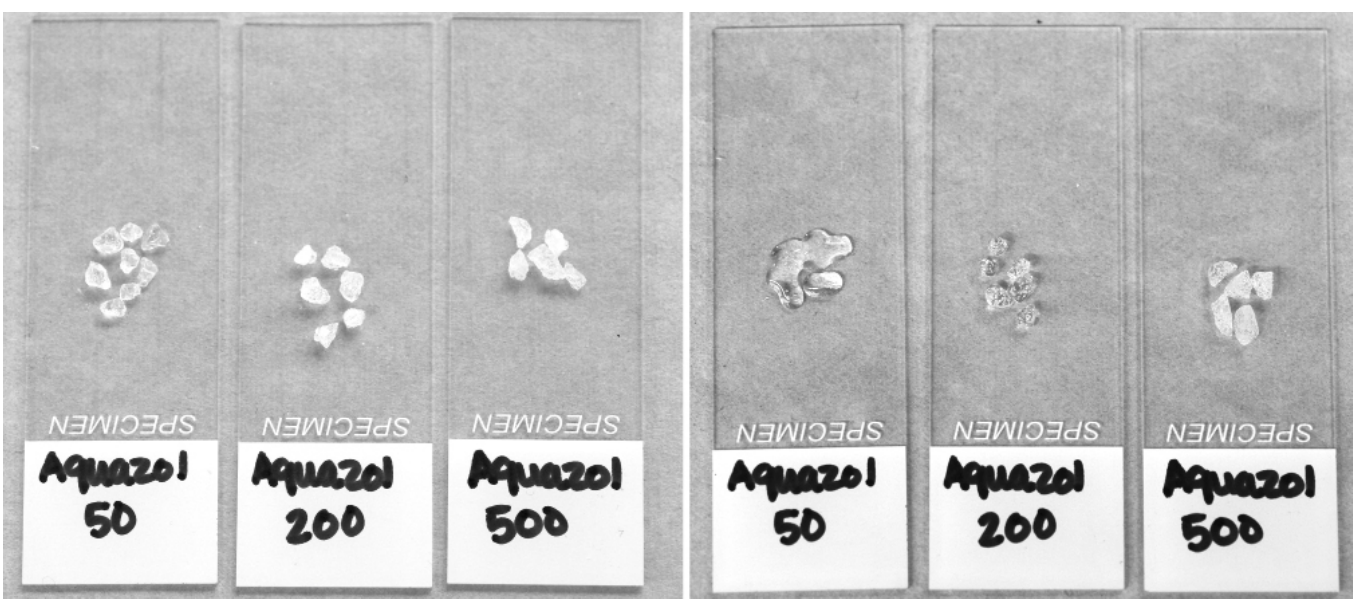
The problem of obtaining solvents in the field was encountered by the author when working on the Pambamarca Archaeological Project (PAP) in northern highland Ecuador. Due to strict government regulations, obtaining solvents such as acetone and ethanol from chemical suppliers, hospitals and conservation labs was extremely difficult. The majority of the work in the conservation lab focused on the reconstruction of ceramics and other small finds. Due to the limited solvents available, finding a suitable adhesive posed problems when surveying the more commonly used synthetic resins for archaeological materials. The only solvents commercially available that could be easily purchased locally were distilled water and a 70% solution of isopropanol in water. Aquazol, with its solubility in both water and isopropanol, was considered as a possible adhesive choice, especially the higher molecular weight polymer Aquazol 500.

Published information on the behavior of Aquazol in high humidity environments raised concerns however. Aquazol was found to be more hygroscopic than other aqueous-based adhesives and thought to lose strength at high humidity (Arslanoglu 2003; Wolbers, et al. 1994). Films of Aquazol 50 and 500 were found to lose adhesion above 75%, with gelling of the adhesive above 84% (Arslanoglu 2003). Failure of a weight bearing join on a glass vessel due to high humidity was reported, though the specific relative humidity (RH) level at which this occurred was not (Arslanoglu 2004). On a site where artifacts are stored in non-climate controlled storage in a region where RH levels can average 59-84% daily (Gladstone 2011a, 2011b), the response of Aquazol to high humidity could pose a problem.

Testing

A series of empirical tests were conducted in order to better understand what the behavior of Aquazol was at various RH levels. Different molecular weights of Aquazol (50, 200, 500) were tested both in the pure resin in granular form and as a film applied to a glass slide. The solvent chosen for the film was 70% isopropanol in deionized water. This particular solvent was chosen for two reasons: previous testing showed that the application of Aquazol in solvents other than water made it less responsive to RH changes (Arslonaglu 2004, 2003) and this was the highest concentration of isopropanol commercially available in the area where PAP was located. 40% solutions of each of the Aquazols (50, 200, and 500) in 70:30 isoproponol: deionized water (v/v)

Figure1 The images shows Aquazol in the pure resin form before (left) and during testing when the humidity reached 80% (right). The granules have altered in response to elevated humidty. The 50 has dissolved and the granules of 200 are shiny, translucent and have solubilized slightly. The 500 has become tacky and appears to have increased in sheen and translucency.



was made. Each solution was brushed onto a glass slide to produce approximately a 1-2mm thick film. 0.05 gr. of each of the pure resins was also placed on glass slides. The samples were kept in a humidity chamber for 6 weeks with the RH slowly increasing from 50-85%. The RH was monitored using both a HOBO H-8 data logger from Onset Corp. and a Lufft dial hygrometer. The samples were examined at each 5% increase in RH for any changes in color, translucency, texture and tack.

Results

Changes were observed in the Aquazol in pure resin form at RH levels as low as 60-65% (figure 1). The Aquazol 50, which was much more hygroscopic than the higher molecular weight resins, became tacky at 60%. At 70% all the resins were tacky. In addition to an increase in tack as the RH rose, changes to the appearance of the granules were also observed. At 65% RH, Aquazol 50 appeared shiny and translucent. At 70% RH, the granules of 50 started to swell and look rounded. At 75%, the 50 began to dissolve and continued dissolving as the RH increased. Similar changes in sheen and translucency of the 200 were observed starting at a slightly higher RH (70%). The granules of 200 began to look slightly rounded at 80% RH and began to solubilize, but the resin did not dissolve to the same extent as the 50. These changes were not observed in the pure resin form of the Aquazol 500, except for becoming slightly shiny at 80% and an increase in sheen and translucency at 85%.

The results of the tests on films gave slightly different results. As discussed by Arslonaglu (2004, 2003), Aquazol made with solvents is much less responsive to changes in relative humidity in comparison to the pure resin form or films made using only water. Changes to the test films made were observed at 65% RH with the Aquazol 50 becoming tacky. As with the tests with the pure resin form, the films made with the higher molecular weight resins were not as hygroscopic. These two films did not become tacky until the RH reached at least 70% in the case of Aquazol 200 and 75% in the case of Aquazol 500. Other than becoming tacky, no other changes were observed to the films (figure 2).

Discussion and Conclusions

Though Aquazol has found success as an adhesive for certain applications (Arslonaglu 2003; Friend 1996; Shelton 1996; Wolbers, et al. 1994), based on the initial results of these tests, it may not be a suitable material to use as an adhesive for ceramics and other archaeological materials when used in environments with elevated humidity levels. The resin appears to be too responsive to increases in RH, starting as low as 60-65%, which could cause softening of the adhesive layer and failure of joins. Though the larger molecular weight resins were not as hygroscopic as the Aquazol 50, with changes in the 200 and 500 films not occurring until the RH reached at least 70%, their use could still be problematic if humidity levels rise, especially when used on weight-bearing joins.

Figure 2

	resin granules			**films**		
RH	**Aquazol 50**	**Aquazol 200**	**Aquazol 500**	**Aquazol 50**	**Aquazol 200**	**Aquazol 500**
50%	No change	No change	No change	No change	No change	No change
55%	No change	No change	No change	No change	No change	No change
60%	Slightly tacky	No change	No change	No change	No change	No change
65%	Tacky; resin becoming translucent, shiny	Slightly tacky	No change	Slightly tacky	No change	No change
70%	Tacky; resin starting to swell; more translucent	Tacky; resin becoming translucent, shiny	Slightly tacky	Tacky	Slightly tacky	No change
75%	Tacky; resin dissolving; granules are transparent	Tacky; increase in shine and translucency	Tacky	Tacky	Tacky	Slightly tacky
80%	Resin dissolved and tacky	Granules slightly rounded, shiny and translucent	Tacky; shiny	Tacky	Tacky	Tacky
85%	Resin dissolved and tacky	Granules rounder, shinier and more translucent	Tacky; shiny, slightly translucent	Tacky	Tacky	Tacky

In addition to the hygroscopicity of Aquazol, the ageing of this resin could potentially pose additional concerns to its use as an adhesive. Ageing tests conducted on Aquazol 50 and 500 found that there is a decrease in the molecular weight of the polymer chain. Samples of Aquazol 500 had a molecular weight close to 300,000 daltons before ageing, with a drop in the molecular weight to 50K daltons after ageing (Wolbers, et al. 1994). Only a small drop in molecular weight was noted in Aquazol 50 after ageing. This may mean that if an Aquazol polymer with a molecular weight greater than 50-60K Daltons is used, there may be adhesive failure as it ages due to a possible scission of the polymer chain (Wolbers, et al. 1994).

Additional testing should be conducted to determine the stability of Aquazol adhesion as it ages and in particular for weight bearing joins on archaeological materials.

Because of its hygroscopicity and changes in molecular weight as it ages, further testing should be undertaken to determine the behavior of Aquazol when used as an adhesive on different inorganic substrates such as ceramics, metals and stone. Tests have found that Aquazol applied to dry pigments or used to consolidate underbound paint is less soluble in solvents (Arslonaglu 2005). Aquazol seems to form complexes with the metal ions in the pigments creating large networks of polymer chains making it less responsive to changes in humidity (Arsonalgu 2005; 2003). This could in turn increase the RH at which failure of joins or loss of strength occurs. What this means in terms of the behavior of the resin within the joins of archaeological material is unclear, but it deserves further investigation.

Until additional tests can be conducted, Aquazol should not be recommended for use as an adhesive in non-climate controlled working or storage environments where humidity exceeds 65-70%, especially if used for weight bearing joins. Aquazol could be considered as an adhesive on archaeological sites in dry climates or where objects are kept in climate controlled storage, however, the changes in molecular weight of the polymer chain over time could potentially affect the stability of objects joined with this resin. For the time being, conservators working on archaeological sites with high humidity or non-climate controlled storage, who cannot readily obtain solvents in the field, will need to continue to look for other alternatives to the resin-solvent systems commonly used on archaeological materials.

Materials and Equipment

Aquazol 50, 200, and 500
Talas
330 Morgan Ave
Brooklyn, NY 11211
212-219-0770
http://talasonline.com/

Glass slides
VWR Micro Slides, Superfrost White
VWR International, LLC.
Radnor, PA 19087
800-932-5000
http://www.vwr.com/

HOBO H-8 data logger
Onset Corp.
470 MacArthur Blvd
Bourne, MA 02532
1-800-LOGGERS
http://www.onsetcomp.com/

Lufft dial hygrometer
Manufactum
Hiberniastr. 5
D-45731 Waltrop
Germany
+49-2309-939 054
http://www.manufactum.com/

References

Arslanoglu, J. 2005. Using Aquazol: A brief summary. *Paintings Specialty Group Postprints* Washington DC: American Institute for Conservation, 107-110.

Arslanoglu, J. 2004. Aquazol as used in conservation practice. *WAAC Newsletter* 25 (1), January, 10-15.

Arslanoglu, J. 2003. Evaluation of the use of Aquazol as an adhesive in paintings conservation. *WAAC Newsletter* 25(2), May, 12-18.

Chiu, T.T., B. P. Thill, and W. J. Fairchok. 1986. Poly (2-ethyl-2-oxazoline): A new water- and organic-soluble adhesive. In J.E. Glass (ed.) *Water-soluble Polymers: Beauty with Performance*. Washington D.C.: American Chemical Society, 425-433.

Friend, S. 1996. Aquazol: One conservator's empirical observations. *WAAC Newsletter* 18(2), May.

Gladstone, P. 2011a. METAR/Synop Information for weather station SEQU (84071) in Quito / Mariscal Sucre, Ecuador. http://weather.gladstonefamily.net/site/84071. Last accessed 12/1/2011.

Gladstone, P. 2011b. Synop Information for weather station 84056 (Tomalon, Ecuador). http://weather.gladstonefamily.net/site/84056. Last accessed 12/1/2011.

Shelton, C. 1996. The use of Aquazol-based gilding preparations. *Wooden Artifacts Group Postprints*, Norfolk, VA. American Institute for Conservation. http://cool.conservation-us.org/coolaic/sg/wag/1996/WAG_96_shelton.pdf. Last accessed 12/1/2011.

Wolbers, R. C., M. McGinn, and D. Duerbeck, 1994. Poly(2-Ethyl-2-Oxazoline): A new conservation consolidant. In V. Dofe and F.C. Hault (ed.) *Painted Wood: History and Conservation*. Los Angeles: Getty Conservation Institute, 514-517.