Historical Exposures to Mother of Pearl the Industrial Experience in North America and Europe: A Cautionary Public Health Tale

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Abstract

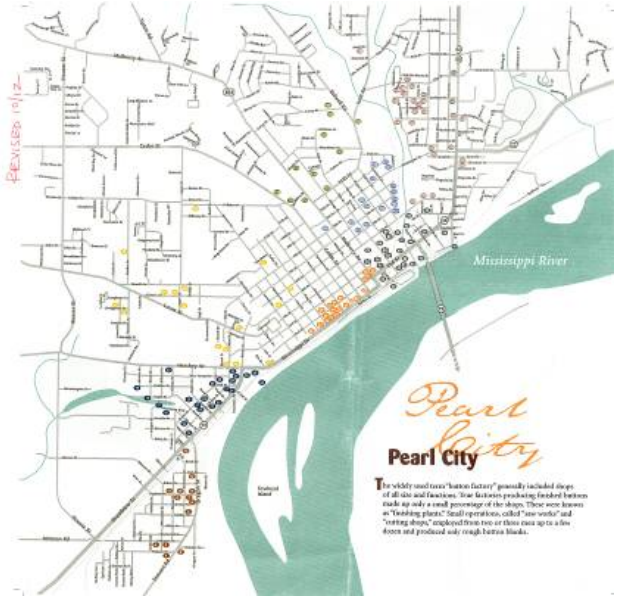
While the expanding field of engineered nanomaterials appears to present new occupational safety and health challenges in the manufacture, handling, and application of these products, there are examples from the past from which we can learn about exposures to nanomaterials and the potential hazards these industrial exposures pose. Public health lessons contained within these examples are relevant to current discussions of nanomaterials issues, including the characterization of exposures, the aerodynamic behavior and biological fate of airborne materials in the nanoscale range, and the epidemiologic investigation of potential health effects for populations with occupational exposures. One such example is the past industrial experience during processing of mother of pearl. While human manipulation of mother of pearl predates recorded history, the industrial scale usage of this material began in the 19th and early 20th century button manufacturing industries. Billions of pearl buttons were produced in hundreds of factories in the United States along the Mississippi River watershed, as well as in Europe. By 1905 over 10,000 people were employed in this trade in the Midwestern United States. The cutting, turning, drilling, and polishing of mother of pearl generated large quantities of respirable dust, with size distributions that included particles suspected to be in the nanometer range. As early as 1832, the injurious influence of pearl button dusts on dermal, ocular and pulmonary systems of exposed British workers was noted. Adverse effects were also noted in remote sites such as the periosteum of bones by German public health authorities and British occupational physician Thomas Oliver. The poorly ventilated pearl button factories of America repeated the continental public health experience resulting in significant morbidity and mortality. The 1909 U.S. Bulletin of the Bureau of Labor recognized health effects manifest as excessive mortality from tuberculosis (TB) among button makers at all ages. This excess mortality was most pronounced at ages 15 to 24 where out every 100 deaths, 50 were caused by TB. This preliminary investigation of nanoscale materials suggests that the past is prologue, and consequently may warrant additional study to improve our understanding of exposures to materials in the nanoscale and the potential hazards they present. Following a research to practice approach, examination of historical accounts for this particular industry will be used to emphasize their utility and relevance for determining characteristics of exposures to nanoscale materials and appropriate guidance and controls in current nanotechnology manufacturing and processes.

Introduction

Nanotechnology, encompassing the study and manufacture of nanoparticles and nanostructured materials, is an emerging field attended with toxicological uncertainties and potential health and environmental concerns. Ultrafine particles including those in the nanometer range possess greater surface area and increased bioavailability, characteristics which give them greater biological activity than the same mass of larger particles of the same or similar chemical composition [1]. While technical and industrial capability allows for industrial production of nanoparticles such as carbon black, our understanding of significant health and safety issues is strikingly incomplete. Another contentious area of nanotechnology with even greater unknowns is the study and duplication of nanomaterials. [2,3]

Scientists and engineers have often found design inspirations in natural materials[3]. Significant efforts have historically been focused on biomemetic and bioduplication efforts to emulate natural designs. Materials scientists are just beginning to understand how simple inorganic calcium compounds like aragonite and calcite and organic polymers can be assembled at the nanolevel into materials having superior strength and fracture toughness. One such nanomaterial is mother of pearl or nacre found in fresh and salt water bivalves. Nacre has intrigued materials scientists for years[2] . Nacre is a perhaps the best known natural nanocomposite, its strength and toughness ascribed to its highly ordered layered 'bricks and mortar' structure[3] . This arrangement provides nacre with strength, hardness, and toughness that is 3,000 times greater than its constituent phases[3,4,5,6] . Nacre has evolved through geological time to a level of optimization not yet currently achieved in engineered composites[2] . While we currently cannot duplicate nacre we do have a very long history of using and manipulating it and exploiting its unique properties and beauty. Examples include Neolithic ornaments, crushed shell tempered pottery crafted by Ohio River Valley Indians, and the manufacture of billions of pearl buttons in the late 19th and early 20th centuries.[7,8]

Pot shard from SunWatch Indian Village/Archaeological Park, Dayton, Ohio. Shell temper was introduced into southwestern Ohio sometime around A.D. 1200 – 1300



If you wanted buttons, you had to buy them in Muscatine, Iowa. [8]

Clamming

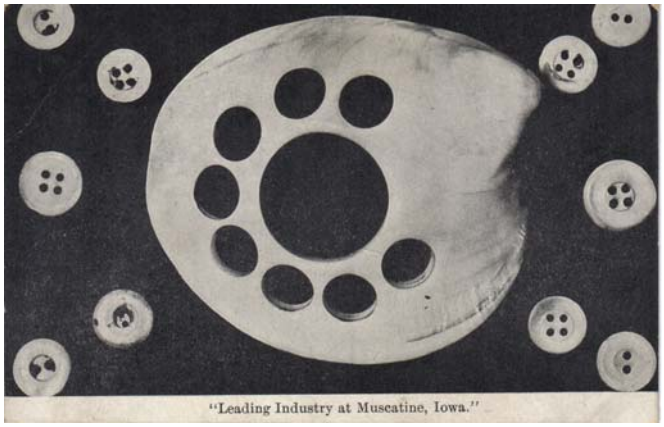
Cutting Room
"It didn't take too much to cut buttons". [8]

Collecting Barge. Large quantities of mussels were routinely collected.

Grinding Room

Pearl Button Blanks

Finishing Room



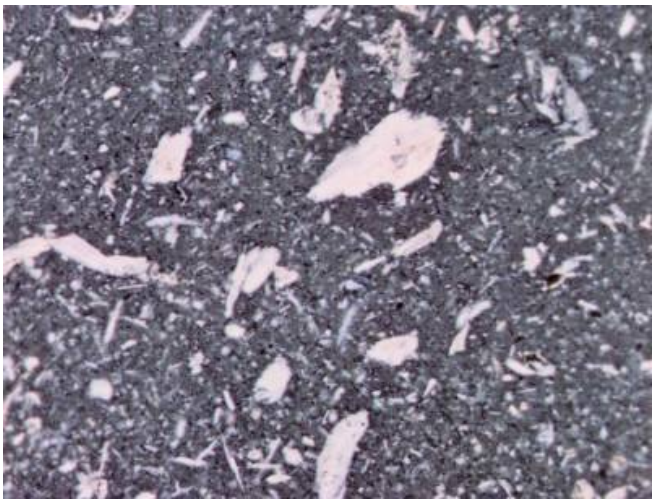
Finished Buttons from Shell

George Gebhardt

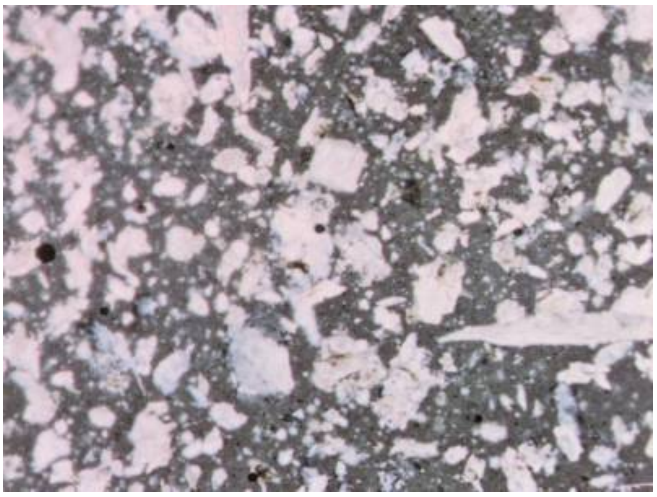
George Gebhardt created a successful business from selling garbage- specifically, the waste shells produced by Muscatine's button industry. Gebhardt created a variety of products from the shells, including "pearl chips" used in aquariums and fish bowls, livestock feed, poultry feed, and natural insecticides. Another significant innovation was the use of shell as "stucco," a protective exterior coating applied to thousands of American houses.

Gebhardt and his Universal Shell Company received national attention when he was featured in the April 1, 1950 edition of Saturday Evening Post. This photo originally appeared as part of that article.

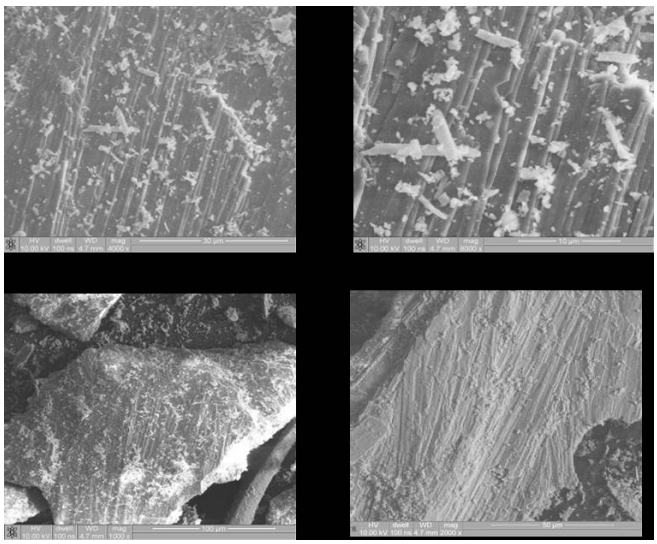
The finished button made up less than 10 percent of the shell's total weight. Between 20 and 30 percent of shell end up as dust during the cutting and finishing processes. The remaining 60 to 74 percent was discarded shell – often used as gravel and fill, and later crushed for marketable byproducts (Gebhardt).



Milled Oyster Shells The fragments appear to be fibrous bundles like those in asbestos (McCrone Associates Particle Atlas)



Pearl Button Dust. (McCrone Associates)



Scanning Electron Micrograph of Freshwater Mollusk Courtesy of Amanda Schrand

Historical Medical Observations

reaching the middle period of life. The superintendent of another factory reported himself to have long suffered from cough and expectoration produced by inhaling the mother-of-pearl dust, adding that this result of the occupation is now so well known that many of the benefit societies of Birmingham will no longer admit pearl-button makers into membership. As might be expected, the disease from which the pearl-button makers suffer in consequence of their trade is chronic bronchitis. This disease runs a very slow course, often lasting many years before finally disabling its subject. Hemoptysis appears to be a not infrequent attendant on the complaint when fully established. ([a])

The inhalation of mother-of-pearl dust is, however, not only injurious to the lungs and air passages, but, as pointed out by Dr. B. W. Richardson in 1876, the dust is also a causative factor in producing a serious disease of the bones, to which the name of "osteitis" has been given to clearly differentiate it from other and perhaps similar afflictions. According to Doctor Richardson, in his lecture on "Unhealthy trades" delivered before the Society of Arts in 1876

Excerpt from Thomas Oliver's Dangerous Trades

The makers of bone buttons are subjected to some dust, but this is not sufficient to produce sensible disorder. The makers of pearl buttons appear to suffer more. The pearl dust produces often bronchial irritation, and this excites pulmonary consumption in individuals predisposed to the disease. Both classes of button makers are, in Birmingham at least, generally intemperate, devoting two days a week to the impairment of their health. ([b])

Halfort, writing in 1845, relies almost entirely upon Thackrah, confirming his conclusions that exposure to the dust of horn and mother-of-pearl is a predisposing cause in bronchial catarrh and in consumption of the lungs.

The first extended inquiry into the hygiene of the employment was made in France during the early fifties, reference to which is made in the report by Dr. Waller Lewis, published as a parliamentary report in 1855. The report calls attention to the generation of large quantities of dust, not only of the material itself but also of the grindstones used in grinding and polishing processes. Of the dust produced in the manufacture of mother-of-pearl, it is stated that—

This dust, of a yellowish white color, is exceedingly abundant; it is very light, and composed of small grains, excessively thin, which give to the touch a rough and sandy sensation. As soon as one enters a workshop where five or six cutters are working, you are suffocated by this dust, and feel a slight smell of animal matter. This odor is due to the composition of the shells, which inclose an organic animal matter, more or less abundant, according to the age of the mollusk, etc. The fibrous and nacreous structure is that part which generally contains most animal matter, and consequently gives off most of the dust. This explains how it is that the water in which the grindstone bathes becomes so quickly putrid, and renders the work of the mill still more insalubrious. ([c])

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[a] Report on Manufactures, Part III, Twelfth Census of the United States, 1900, p. 323.

[b] Effects of Arts, Trades, and Professions on Health and Longevity, by C. Turner Thackrah, 1832, p. 55.

[c] Parliamentary Report, The Laws and Ordonnances in Force in France for the Regulation of Noxious Trades and Occupations, by Dr. Waller Lewis, p. 59.

makers. The following detailed tabular presentation of the proportionate consumption mortality by divisional periods of life shows an excessive mortality from consumption among button makers at all ages. The excess is most pronounced at ages 15 to 24, when out of every 100 deaths from all causes 50.0 were caused by consumption against a normal expected proportion of 27.8.

PROPORTIONATE MORTALITY FROM CONSUMPTION AMONG **BUTTON MAKERS,** 1897 TO 1906, COMPARED WITH THAT OF ALL MALES IN THE REGISTRATION AREA OF THE UNITED STATES, 1900 TO 1906, BY AGE GROUPS.

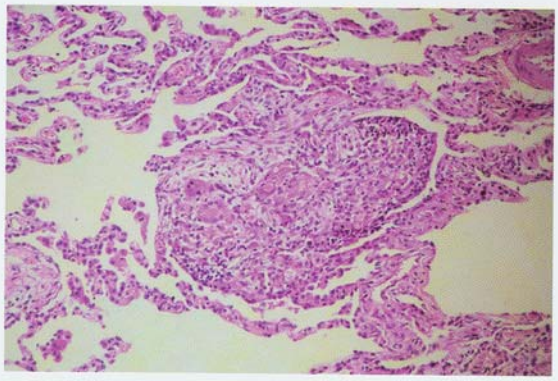
[Figures for button makers from experience of an industrial insurance company; figures for males in registration area computed from mortality statistics of the United States census.]

Age at death.	Deaths of button makers, 1897 to 1906, due to—		Per cent of deaths due to consumption among—	
	All causes.	Consumption.	Button makers.	Males in registration area, 1900 to 1906.
15 to 24 years	24	12	50.0	27.8
25 to 34 years	31	16	51.6	31.3
35 to 44 years	32	12	37.5	23.6
45 to 54 years	24	6	25.0	15.0
55 to 64 years	6	1	16.7	8.1
65 years and over	10	1	10.0	2.7
Total	127	48	37.8	14.8

The mortality statistics of industrial insurance experience fully confirm the preceding observations and quite conclusively prove that button makers as a class are exposed to conditions more or less injurious to health and life. The industry is one of sufficient importance to warrant a more thorough and qualified investigation than has thus far been made.

Recent Medical Observations of Pearl Workers

Within the last twenty years pearl workers in Spain and Japan employed cutting and grinding pearl have been diagnosed with hypersensitivity pneumonitis (HP). [9,10,11] Hypersensitivity pneumonitis (extrinsic allergic alvelitis) is an immunological mediated reaction to a variety of antigens. It appears that the protein found in nacre is just one more different antigens capable of causing HP. The clinical features of (HP) can include fevers, chills, cough, difficulty breathing, fatigue, and weight loss. [9] HP can lead to chronic end stage lung disease. Is it possible that earlier medical observers mistook (HP) for TB? In Spain one woman exposed to aerosolized solutions of pearl antigens developed Alveolar-Septal Amyloidosis a rare and usually fatal disease characterized by the presence of amyloid in the lung. [13] This woman after a year without exposure to the pearl antigens showed no trace of either the pneumonitis or amyloidosis. [13]



COLOR FIGURE 27-5

Hypersensitivity pneumonitis. A few poorly formed granulomas are present in the lung, associated with lymphocytic inflammation. *(Courtesy of Richard Sobonya, MD, University of Arizona.)*

Discussion

The American pearl button industry prospered for decades but ultimately the labor and natural resource intensive business went into decline, finally being replaced by the manufacture of inexpensive and more efficient plastic buttons. Currently there are no more pearl button manufacturing industries in America, yet the legacy of this industry contains public health lessons which may be relevant to discussions of current and future manipulation of engineered nanomaterials. The observations and descriptive toxicology of early public health pioneers in America, England, and German and the recent observations in the Spanish pearl industry support the current concerns derived from cell culture and animal bioassays regarding nanotechnology. [1,10,11] That is the manipulation and inhalation of structured nanomaterials like nacre, given inadequate industrial ventilation and other workplace precautions, is likely to promote acute and chronic pulmonary inflammation and adversely affect remote sites. [12] Current cell culture work demonstrates that water-soluble extracts from nacre are capable of having osteogenic influences. [15] Perhaps this explains the bone complaints of early pearl button workers, working in conditions where industrial processes resulted in inhalation of nanoscale dusts under with inadequate ventilation and other controls.

While inhalation of nacre is problematic it should not be forgotten that ingestion of nanomaterial such as chicken feed, pill binding agents (excepients) and calcium supplements derived from bivalves like oysters is commonplace. After exposure to billions of birds and decades of use in pills and calcium supplements, finely powered oyster shell derived from nanomaterial appears to be safe and is generally recognized as such.

Bioinspired anthropogenic nanomaterials are not yet a commercial reality. However, this could likely change when aragonite/calcite nanostructure materials become viable.

References

1. Warheit,D.B., Effects of Nanoengineered Particulates on the Lung in Toxicology of the Lung 4th Ed edited by. Donald Gardner, Taylor and Francis, Boca Raton, Fl 2006.
2. Checa, A., and Rodriguez-Narro, A., Self-organization of nacre in the shells of Pterioida (Bivalvia:Mollusca) Biomaterials 26 (2005) p 1071-1079.
3. Katti, K.S., and Katti, D., Why is nacre so tough and strong? Materials Science and Engineering C Vol. 26 (8) Sept 2006 p 1317-1324..
4. Stempfle, P., and Brende, M., Tribological behavior of nacre- Influence of the environment on elementary wear processes. Tribology International Vol. 39, (12) December, 2006 p 1485-1496.
5. Neves, N.M., and Mano, J.F., Structure/ mechanical behavior relationships in crossed-lamellar sea shells. Materials Science and Engineering C Vol 25 (2) 28 April 2005 p 113-118.
6. Barthelal, F., Tang, H., Zavattieri, P.D., Li, C.M., Espinosa, H.D., On the mechanics of mother of pear: A key feature in the material hierarchical structure. Journal of the Mechanics and Physics of Solids
7. Feathers, J/F. Explaining Shell-Tempered Pottery in Prehistoric Eastern North America. Journal of Archaeological Method and Theory, Vol 13 (2) June 2006. p89-132.
8. Oral Histories from the Iowa Labor History Collection. State Historical society of Iowa. 1982.
9. Teprano, J., Knutsen, A.P., Slavin, R.G., Hypersenistivity Pneumonitis. Current Pediatric Reviews Vol 1 Nov. 2005, p 265-281.
10. Mitani, M., Satoh, K., Kobays\ashi,T., Kawase, Y., Hosokawa, N., Takashima, H., Kobashi , S., and Tanable, M., Hypersensitivity pneumonitis in a pearl nucleus worker. J. Thoracic Imaging, 1995 Spring 10 (2) 134-7.
11. Orriols, R., Li, J., Aliaga, J.M. High prevalence of mollusc shell hypersensitivity in nacre factory workers. Eur. Respir. J. 1997 Vol 10 p 780-786.
12. Oliver, T., Dangerous Trades: The Historical , Social, and Legal Aspects of industrial Occupations As Affecting Health by a Number of Experts. London: John Murray Ltd. 1902.
13. Aliaga, L., et al. Localized alveolar-septal amyloidosis with hypersensitivity pneumonitis. The Lancet Vol 339 n. 8804 (23 May 1992) p1261-2.
14. Thackrah, C.T., The Effects of the Principal Arts, Trades, and Professional and Civil States and habits of Living on Health and Longevity with Suggestions for removal of Many Agents Which Produce Disease and threaten the Duration of Life. 1831. reprinted by W.H. Smith , London, 1989.
15. Moutahir-belqasmi, F., et.al Effects of water soluble extract of nacre (Pinctida maxima) on alkaline phosphatase activity Bcl 2 expression in primary culture osteoblasts from neonatal rat calavaria. Journal of Material Science Materials in Medicine. Vol 12(1) Jan 2001.

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