EFFECT OF CHLORINE ON HUMAN HAIR

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Background, Purpose and Hypothesis

I have been swimming for many years, without ever wearing a swim cap, and have always had brittle and dull hair. I suspected it was the chlorine that damaged my hair: making it dry, brittle, dull and bleached. This is an investigation of the effects that the different levels of chlorine in the swimming pools and spas have on human hair.

All swimmers have experienced damaging effect of chlorinated water in a swimming pool or spa on their hair. In order to understand how the chlorine is damaging hair, we need to learn first about hair and chemicals used to treat water.

According to “The World of Hair” [1], hairs are built mainly with keratin, a protein, whose major constituents are amino acids. Hairs are covered with natural oil (sebum) that gives hairs their shine and flexibility. The colour of hair depends on relative content of each of the two melanin variants.

The chlorine is added to water in the swimming pools and spas in order to reduce the growth of microorganisms, such as bacteria and viruses [3]. The chlorine that is able to sanitize contaminants is called “free” chlorine. The level of “free” chlorine in swimming pool should be between 1 and 3 ppm (parts per million), and between 3 and 5 ppm for spas [2], [3]. The total amount of chlorine in water is sum of “free” active chlorine and “combined” inactive chlorine, which has reacted with contaminants. Other chemical properties of water, which have to be controlled because of the effect they have on water and pool equipment, are: total hardness, total alkalinity and pH, which measures relative acidity/alkalinity of water.

Chlorine (hypochlorous acid) reacts quickly with organic and non-organic materials present in swimming pool water. Because of its chemical activity, chlorine also affects hair of swimmers. Chlorine affects hair by direct chemical reactions resulting in chemical changes to hair components, by changing physical properties of the hair, as well as by changing electrical charge of minerals bonded to hair and reacting with those minerals.

The direct chemical changes include reactions of chlorine with pigments giving hair their colour, oils covering hair and proteins forming hair shafts. The reaction of melanin pigments with chlorine results in change of hair from natural colour (blond to black) to straw colour of keratin. Chlorine removes natural oils covering hair resulting in loss of hair shine and flexibility, as well as making them more susceptible to mechanical damage. Reaction of chlorine with keratin results in creation of water-soluble chemicals and weakens chemical bonds between fibers forming hair shafts. Also chlorine can get between the hair fibers. As the crystallization process develops inside the hair, the chlorine crystals can separate the hair fibers disrupting structural integrity of hair shaft. Once the bonds are broken, the hair becomes weak and ends of the hairs split. Chlorine salt crystallization process may also affect the hair cuticle. The cuticle is an outer layer of very hard, dead cells over the hair surface. If the chlorine gets between the scales it could push up the scales; therefore, making it rough. These flaked cuticles reflect light poorly and so the hair fiber looks dull, dry and may feel rough when touched [4].

Chlorine can change electrical charge of minerals bonded to hair and oxidize those minerals.

Procedures

The constants in the study were: temperature, and the length of time samples were submerged in the chlorine solutions. The tested variables were: chlorine concentrations (0, 1 ppm, 5 ppm, 10 ppm) and the initial hair condition (natural dark blond, coloured light auburn, coloured blue-

black). The responding variables were: colour, texture and degree of damage, as observed under microscope. A sample of each of the three hair colours was put in separate containers with three solutions of chlorine and the one container of water used as a reference. Each day for the next two weeks each sample was removed, examined under bright light, and photographed. The solutions in containers after removal of the hair samples were tested with strips for total chlorine and free chlorine. Fresh solutions were used to maintain the chlorine concentration. Also the solutions were tested for total hardness, pH, and total alkalinity. The colour of solutions was examined under bright light against a white paper background

After 14 days the all hair samples were removed from the containers, and left exposed to room temperature air to dry out. The dried hair was examined under bright light. A microscope slide using natural dark blond samples was made using an untreated hair, one from the clear water reference, and one from each of the three chlorine solutions. Similar slides were made for the other colours. Each slide was examined and photographed.

Observations and Conclusions

Since distilled water was used the total hardness and total alkalinity were very low and did not change after 1 day. The “pH” remained at the 6.2-6.8 range.

Both the total chlorine and free chlorine concentration decreased from initial levels of 10 and 5 ppm to 0.5-1 ppm after 1 day. The sample with the initial 1 ppm chlorine level dropped after one day to be undetectable using test strips. This would suggest that the chlorine was reacting and bonding with hair. Also some chlorine was escaping into air.

During the first 3 days solutions with artificially coloured hair samples had gained visible colour. The colour of 10 ppm solutions was darker than colour of solutions with lower chlorine concentrations. The colour intensity decreased after each day. After 4 days, the coloured hair

sample lost much of the original colour intensity. The auburn hair in 10 ppm solution looked nearly like untreated natural blond hair. The black hair still kept some black colouring. After 5 days, only 0 ppm solution with black hair showed some colour. After 6 days and until end of the test no discolouration of the solutions was noted after removal of hair samples.

To the naked eye, the hair samples were gradually loosing shine and becoming matted. However, none of the samples, even in the 10 ppm solution after 14 days, became completely bleached (i.e., straw coloured). The hair samples were still maintaining some of their original dark blond colouring (for natural and auburn hair samples) or slightly darker than the original untreated hair (for black treated hair).

When examined under the microscope, the following observations were noted:

- The major differences between hair samples in the different chlorine solutions were in the condition of the hair cuticles. The hair in the solution that had the highest concentration of chlorine were the most damaged, meaning the hair lost its shingle like exterior structure and become nearly transparent.
- The hair in solutions with lower chlorine concentration had less damaged cuticles with shingles still visible on surface and some colour remaining.
- There was little difference in condition of the surface of the reference hair (not dipped in water nor in chlorine solution) and hair dipped in distilled water (0 ppm of chlorine). However, the hair in the distilled water lost some colour and the samples under the microscope were visibly lighter than the reference hair.
- In general, the red hair samples were more damaged than natural and black coloured hair in the solutions with the same chlorine concentration.

The results indicate that chlorine does some damage to hair. However, after 14 days the changes in the hair samples at the tested chlorine concentration levels were fairly small and thus difficult to quantify when observed by naked eye. The observations under microscope indicate that the solutions with high concentrations of chlorine were causing more damage than those with low concentrations.

The observations indicate that the chlorine in concentrations normally expected in the swimming pools and spas may not be solely responsible for the damage to the hair of frequent swimmers and some additional factors (such as heat drying, other chemicals present in water, hair treatments, etc.) may contribute to hair damage.

Information from this project can help swimmers and pool owners/operators understand impact the chlorine has on hair.

Acknowledgements and Bibliography

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My hypothesis is based on the information collected from the following sources:

1. "The World of Hair" Dr. John Gray www.pg.com/science/haircare
2. "Swimming Pool and Spa Sanitation" Health Canada, April 1999.
3. "The Complete Guide to Pool and Spa Care" AquaChek
4. www.keratin.com
5. "How Does Ultraswim Remove Chlorine" by Larry Lippman @ Recognition Research Corp. yarchaive.net/chem/shampoo
6. www.hair-science.com by L'Oreal.