CHAPTER XIX

Cause and Removal of Color

Color removal was rarely if ever attempted until the latter part of the nineteenth century. Even since then it has seldom been accomplished except when incidental to some other objective of treatment or as an important adjunct to storage. In the early days of filtration of public water supplies, the term "color" was often used when turbidity would have been more accurate.

A clear concept of the difference between turbidity and color was shown by Dr. John Bostock * in a paper published in 1830 (1). He stated that New River water at London after heavy rains in December, 1827, was "very turbid and dark coloured," but after some hours of sedimentation, although the water was nearly transparent, "the dark colours still continued." Neither boiling nor filtration through sand and charcoal removed the color, but "alum and certain metallic salts, especially when heated, threw down a precipitate, and left the water without colour." The most efficient of the metallic salts "appeared to be the sulphate of iron," but the water treated by it had been boiled.

William West, also in 1830 (2), wrote that color was "quickly and completely separated by aluminous earth in a state of minute division." It was also separated by muriate of tin. It "obstinately resists mere filtering . . . yet sand, containing, as I apprehend, some alumine [*sic*] is effectual in separating it." Exposure to air in a reservoir also removed color.

A notable essay on color in water was published in 1862 by Professor Wilhelm von Beetz, a German physicist (3). He reviewed theories advanced by his immediate predecessors and also the much earlier discussion by Sir Isaac Newton (paper on light and color contributed to the Royal Society in 1675, included in Newton's *Optics*, 1704). In his review of the conclusions of his immediate predecessors, which he endorsed in general terms, Beetz wrote:

[Robert Wilhelm] Bunsen (Liebig's *Annalen*, 62: 44) was the first to state, and establish experimentally, the simple proposition that "chemically pure

* See also statement by Robert Spurr Weston near end of this chapter.

water is not, as commonly assumed, colourless, but naturally possesses a blue colour." He observed this coloration on looking at a piece of white porcelain through a column of water two yards long. He explained the brown to black colouration of many waters, especially of North German inland lakes, as arising from an admixture of humus; the green colour of the Swiss lakes, and, still more so, the siliceous springs of Iceland, as arising from the colour of the yellowish base, and of the siliceous sinter surrounding the springs, and which is caused by traces of hydrated oxide of iron. Wittstein (*Sitzungsber. der K. bayer,* Akad. der Wissensch, in München, 1860, p. 603), by careful chemical investigations, has quite recently shown that the green colour also derives its origin from organic admixtures. According to him, the less organic substance a water contains, the less does its colour differ from blue. With the increase of organic substances, the blue gradually passes into green, and from this, as the blue is more and more displaced, into brown. Water is softer the nearer it is to brown, and harder the nearer it is to blue; this does not arise from a greater or less quantity of organic substance, but of alkali, on which, again, the proportion of dissolved organic substance depends. This alkali dissolves the organic substance in the form of humic acid. If a water does not contain much humic acid, this is not caused by a want of humic acid in the ground, but by the fact that this ground did not give to the water an adequate quantity of alkaline solvent material.

From these results we may consider the question settled as to why, on chemical principles, some waters are blue, others green, and others brown.

The remainder of Beetz's essay describes his and other studies of color with reflected and with transmitted light, rather than with the organic or mineral contents of the water employed. His apparatus is illustrated by several drawings.

A long series of papers by Walthère Spring, a Belgian attached to Liege University, was published in 1883–1910. He reported in 1897 that ferric compounds, acting on humic bodies in upland bog waters would reduce color and that light aided the reaction and was possibly necessary.*

The first American recorded study of color removal was made in 1874 by a Medical Commission created to report on the relative merits of the Sudbury River and other possible sources of water supply for Boston (5). In a supplementary report the commission summarized laboratory studies on the effect of storage and exposure to light. The studies showed that the color diminished as the intensity

* These studies were called to my attention in 1940 by Frank Hannan of Toronto. He states that Spring's studies on the source of color in water make up a part of his collected works (4), the larger part of which is written in French while the remainder is in German.

of the light increased. This reinforced the commission's arguments on the benefit of storage of surface supplies in large reservoirs. Telescopic glass tubes and reflecting prisms were used in these studies.

Desmond FitzGerald directed more elaborate studies of color removal at the Chestnut Hill laboratory of the Boston water works in 1886–94 (6). The studies were in direct charge of F. S. Hollis. It was concluded that not iron, as was first assumed, but carbonaceous matter was the source of color in the surface waters studied. Exposure of water to the sun in gallon-sized glass bottles resulted in complete removal of color. These studies provided data in favor of long storage in reservoirs to improve the quality of water.

Color Removal at Greenock, Scotland

The earliest known instance of removing color from a public water supply occurred in 1827 in Greenock, Scotland. Water for a gravity domestic and power supply was impounded from an upland area much of which yielded "moss water" carrying color and "other dissolved matter." So far as feasible, the colored water was excluded from the reservoir storing the domestic supply. To remove color from any moss water reaching the filters, amygdaloid crushed to pea size or smaller was mixed with the sand used in Robert Thom's "self-cleansing" or reverse-flow wash filter. He was led to do this by observing that in the moss lands the water of springs emerging from trap rock or amygdaloid was clear as crystal. Such rock was abundant in the hills about Greenock but it was somewhat costly and in time became "saturated" and had to be replaced. Eventually, animal charcoal seems to have been substituted for amygdaloid (see Chap. V). Thom did not explain why amygdaloid removed color. It is an igneous rock containing almond-shaped cavities (hence the name) filled with such foreign matter as quartz, calcite or a zeolite.

John R. Baylis, Engineer of Water Purification, City of Chicago, Frank Hannan, formerly Chemist, Filtration Plant, Toronto, Canada, and Robert Spurr Weston, Consulting Chemist and Engineer, Boston, kindly read the first draft of this chapter and sent comments and supplementary data as follows:

Baylis: In regard to the use of amygdaloid for color removal at Greenock, I cannot see how the material we now know as amygdaloid would effect color removal. I suspect the material which Thom classified as this substance was some other material [see below].

There is the possibility that the color was in suspension and not in solution. I know of a few instances in which filtering water through a Berkefeld or a porcelain filter has removed color. Such removal I feel confident was by straining and not by absorption of the color on the surfaces of the filter media.

Hannan: [Amygdaloid.] I think that it is now generally admitted that the color due to humus bodies is colloidal and negatively charged. As such, it resists filtration; but when a suitable proportion of positively charged colloid (such as are the metallic hydroxides, as a class) is introduced, coagulation follows with resultant precipitation, removable by filtration. My *guess* would therefore be that the amygdaloid probably supplies in colloidal form either ferric or aluminum hydroxide in adequate quantity. (For decomposition of rocks, see *Data of Geochemistry,* U.S. Geological Survey Bulletin 770, 12: 479–542, by Dr. Frank Wigglesworth Clark.)

Weston: [Questions statement on use of amygdaloid at Greenock.] Regarding the distinction between turbidity and color, the A.P.H.A.-A.W.W.A. *Standard Methods of Water Analysis* use two terms, namely "true color" and "apparent color," the first being the color of water after filtration through paper. This color may be due in part to matter in colloidal suspension, that is, to particles too fine to be removed by short periods of subsidence.

Color is due primarily to chlorophyll which is a compound of iron and organic matter, sometimes in colloidal suspension, sometimes in true solution. The brown color of surface waters is due to the oxidation of the iron, the same that takes place when the sap is withdrawn from the leaves in the fall and the autumn colors brighten the landscape. This same brown iron-organic color is dissolved from the leaves on the surface of the ground, from the loam beneath, and from the mosses and peat in the swamps.

I am glad that you have emphasized the color removal by storage, which is of course due to bacterial decomposition, coagulation, and resulting subsidence, and also to the bleaching action of sunlight. A few years ago I looked up the matter of removal by storage and found that on the average half of the color was removed in 350 days and about 75% in 760 days.

Other Experience in Color Removal

Thomas Spencer, in a paper published at London in 1859, claimed removal from water of matters in solution: color, "other impurities and taste." After experiments with other materials he found protocarbide of iron the best for the purpose. By roasting red hematite of iron he produced carbide of iron, or magnetic oxide. This, mixed with fine sand, was used as a layer in a filter beneath a top layer of fine sand. Subsequently, the Spencer Process was adopted at Wakefield, Stockport and Wisbeach, England. At Wakefield the water treated received dye and other wastes from factories built on the River Calder after that stream was chosen as a source of supply. At Wisbeach the water was discolored by peat and at Stockport well water was colored by "iron rust" (see Chap. XIII).

With the advent of rapid filtration in the eighties and nineties color removal became increasingly common in the United States. Notable among the highly colored waters so treated was the supply of Norfolk, Va., where a rapid filtration plant was completed in 1899 (7). An exceptional case of decolorization is afforded by Springfield, Mass., where excess coagulation with sulfate of alumina was begun in 1911, a year after the sand filtration plant with precoagulation was put into use (8).

Ozonation for reduction of color, as well as tastes, odors and bacteria, was adopted at Long Beach, Ind., in 1930, and was being studied diligently in experimental and demonstration plants in 1941–42 (see "Ozonation" in Chap. XIV).

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Chapter XIX

Cause and Removal of Color

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