CHAPTER 2

Contaminant Concentration Reduction

Waste strength reduction is the second major objective for an industrial plant concerned with waste treatment. Any effort to find means of reducing the total pounds of polluting matter in industrial wastes will be well rewarded by the savings earned by reduced requirements for waste treatment. The strength of wastes may be reduced by: (1) process changes; (2) equipment modifications; (3) segregation of wastes; (4) equalization of wastes; (5) by-product recovery; (6) proportioning wastes; and (7) monitoring waste streams.

Process Changes

In reducing the strength of wastes through process changes, sanitary engineers are concerned with wastes that are most troublesome from a pollutional standpoint. Their problems and therefore their approach differ from those of plant engineers or superintendents. Sometimes tremendous resistance by a plant superintendent must be overcome in order to effect a change in process. Superintendents possess considerable security because they can do a familiar job well. Why should they jeopardize their position merely to prevent stream pollution? The answer is obvious. Industry dies when its progress stops. No manufacturer can meet present-day market competition without continually, and critically, reviewing and analyzing its production techniques. In addition, pollution abatement can no longer be considered by industry as a "optional" act; on the contrary, it must be regarded as a vital step in preserving water resources for all users. Many industries have resolved waste problems through process changes. Two such examples of progressive management are the textile and metal-fabricating industries. On the other hand, the leather industry still generally uses lime and sulfides (major contaminants of tannery wastes), although it is known that amines and enzymes could be substituted. The lag between research and actual application is often extensive, and is caused by many operational difficulties.

In a detailed study of the iron and steel industry, your author (Nemerow 1976) revealed three major process changes that resulted in reduced environmental pollution load:

1. Dry quenching of coke (instead of wet quenching)
2. Hydrochloric acid pickling (instead of sulfuric acid pickling)
3. Direct reduction of iron ore (instead of coking and blast furnace plants)

Textile-finishing mills were faced with the disposal of highly pollutional wastes from sizing, kiering, de-sizing, and dyeing processes. Starch had been traditionally used as a sizing agent before weaving, and this starch, after hydrolysis and removal from the finished cloth, was the source of 30–50% of the mill's total oxygen-demanding matter. The industry began to express an interest in cellulosic sizing agents, which would exhibit little or no biochemical oxygen demand (BOD) or toxic effect in streams. Several highly substituted cellulosic compounds, such as carboxymethyl cellulose, were developed and used in certain mills, with the result that BOD contributed by de-sizing wastes was reduced almost in direct relation to the amount of cellulosic sizing compound used.

In the metal-plating industries (Davis 1957), seven changes of process or materials were suggested to eliminate or reduce cyanide strengths: (1) change from copper-cyanide plating solutions to acid-copper solutions; (2) replace the $CuCN_2$ strike before the copper-plating bath with a nickel strike; (3) substitute a carbo-nitriding furnace, which uses a carburizing atmosphere and ammonia gas, for the usual molten cyanide bath; (4) use "shot blasts" or other abrasive treatment on nonintricate parts instead of H_2SO_4, in pickling of steel; (5) substitute H_3PO_4 for H_2SO_4 in pickling; (6) use alkaline de-rusters instead of acid solutions to remove light rust, which occurs during storage (the overall pH will be raised closer to neutrality by this procedure, which will also alleviate corrosive effects on piping and sewer lines); and (7) replace soluble oils and other short-term rust-preventive oils applied to parts after cleaning with "cold" cleaners. These cleaners can be used in both the wash and rinse solutions. They inhibit rust chemically rather than by a film of oil or grease.

A Pennsylvania coal-mining company modified its process to wash raw coal with acid mine waste rather than a public or private water supply. In this way, the mine drainage waste is neutralized while the coal is washed clean of impurities. In one analysis, for example, the initial mine water had a pH of 3, an acidity of 4,340 ppm as $CaCO_3$, and an iron content of 551 ppm. The wastewater finally discharged from the process had a pH of 6.7–7.1 and an iron content of less than 1 ppm.

Equipment Modifications

Changes in equipment can reduce the strength of the waste, usually by reducing the amount of contaminants entering the waste stream. Often quite small changes can be made in present equipment to reduce waste. For instance, in pickle factories, screens placed over drain lines in cucumber tanks prevent the escape of seeds and pieces of cucumber, which adds to the strength and density of the waste. Similarly, traps on the discharge pipeline in poultry plants prevent emission of feathers and pieces of fat. Your author (Nemerow 1977) recommended another procedure for accomplishing pollution reduction by equipment modification. The method is to change the production procedure to "dry-collect" as much waste material as possible from manufacturing machines and operating floors rather than "hosing down" the same matter into drains.

An outstanding example of waste strength reduction (with a more extensive modification of equipment) occurred in the dairy industry. Trebler (1944) redesigned the large milk cans used to collect farmers' milk. The new cans were constructed with smooth necks so that they could be drained faster and more completely. This prevented a large amount of milk waste from entering streams and sewage plants. Dairy farmers also installed drip pans in assembly lines to collect milk that drains from the cans after they have been emptied into the sterilizers. The drip-pan contents are returned to the milk tanks daily.

In the chemical industry, Hyde (1965) described a chemical plant that achieved a 23% decrease in average BOD through the installation of calandrias on open-bottom steam stills and by using refrigerated condensers ahead of vacuum jets, among other process modifications.

Segregation of Wastes

Segregation of wastes reduces the strength or the difficulty of treating the final waste from an industrial plant. It usually results in two wastes: one strong and small in volume and the other weaker, with almost the same volume as the original unsegregated waste. The small-volume strong waste can then be handled with methods specific to the problem it presents. In terms of volume reduction alone, segregation of cooling waters and storm waters from process waste will mean a saving in the size of the final treatment plant. Many dye wastes, for example, can be more economically and effectively treated in concentrated solutions. Although this type of segregation may increase the strength of the waste being treated, it will typically produce a final effluent containing less polluting matter.

Another type of segregation is the removal of one particular process waste from the other process wastes of an industrial plant, which renders the major part of the waste more amenable to treatment, as illustrated in the following examples.

A textile mill manufacturing finished cloth produced the wastes listed in Table 2.1. The combined waste was quite strong, difficult and expensive to treat, and very similar to laundry waste. However, when the liquid kiering waste was segregated from the other wastes, chemically neutralized, precipitated, and settled, the supernatant (the part that remained on the surface) could be treated chemically and biologically along with the other three wastes, because the strength of the resulting mixture was considerably less than that of the original combined waste. This type of segregation is also practiced in metal-finishing plants, which produce wastes containing both chromium and cyanide, as well as other metals. In almost all cases, it is necessary to segregate the cyanide-bearing wastes, make them alkaline, and oxidize them. The chromium wastes, on the other hand, have to be acidified and reduced. The two effluents can then be combined and precipitated in an alkaline solution to remove the metals. Without segregation, poisonous hydrogen cyanide gas would develop as a result of acidification. A method was patented (Koelsh-Folzer-Werke 1966) that allows the separation of

TABLE 2.1
Wastes from a Textile Mill

	Gray Water	*White Water*	*Dye Waste*	*Kier Waste*	*Combined Waste*
pH	4.0	7.3	11.0	11.8	9.4
Total solids, ppm	2,680	420	2,880	18,880	1,560
Suspended solids, ppm	224	67	148	218	156
Oxygen consumed, ppm	1,560	31	556	4,900	460

paint from wastewater by precipitation with ferric chloride and/or ferric sulfate, along with calcium hydroxide.

In treating the waste of a large poultry plant, the blood from the killing room floor was interfering with the treatment of the remainder of the chicken waste. Nemerow and Dasgupta (1991) recommended that the blood be scraped, swept, and disposed of with the screenings. In this way, a high BOD waste was segregated from the remaining plant process waste and treated separately.

Segregation of certain wastes is of great advantage in all industries. It is dangerous, however, to arrive at a blanket conclusion that segregation of strong or dangerous wastes is always desirable. Just the reverse technique—complete equalization—may be necessary in certain circumstances.

Equalization of Wastes

Plants that have many products from a diversity of processes prefer to equalize their wastes. This requires holding wastes for a certain period, depending on the time taken for the repetitive processes in the plant. For example, if a manufactured item requires a series of operations that take 8 hours, the plant needs an equalization basin designed to hold the wastes for that 8-hour period. The effluent from an equalization basin is much more consistent in its characteristics than each separate influent to that same basin. Stabilization of pH and BOD and settling of solids and heavy metals are among the objectives of equalization. Stable effluents are treated more easily and efficiently than unstable ones by industrial and municipal treatment plants. Sometimes equalization may produce an effluent that warrants no further treatment. The graph in Figure 2.1 illustrates one of the beneficial effects of equalization.

A large chemical corporation producing a predominantly acid waste found it advantageous to equalize its wastes for a 24-hour period in an earthen holding basin. After this equalization, a nearby plant, producing a highly alkaline waste, pumped its waste into the acid-waste effluent for neutralization. Considerably greater neutralizing power would be required for the acid waste were it not equalized to iron out the peaks before neutralization.

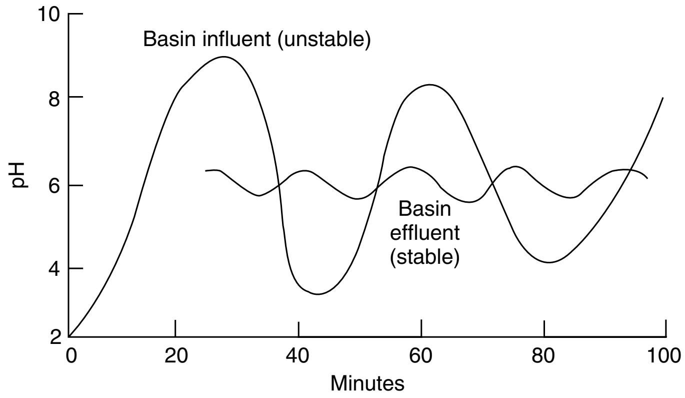

FIGURE 2.1. Time elapsed after start of equalization.

Salt in large quantities is used to "cure" cucumbers into pickles. The salt brine waste represents a large volume percentage of the total processing waste and can cause disproportionate objectionable effects when discharged into a receiving water. In at least one case in which your author was involved, I recommended holding the brine wastes in large vats for slow discharge with the remaining plant waste over long periods. In this way, the total plant waste was equalized with the brine wastes to minimize the salt effect.

A textile-finishing mill that discharged its waste into a domestic secondary sewage-treatment plant upset the efficiency of the plant. Although this waste represented only about 10% of the total being treated, it caused fluctuations, primarily in pH and BOD, which were responsible for the plant's difficulties. The solution was to build an equalization basin capable of detaining the waste long enough to reduce the fluctuations in pH and BOD. In addition, the mill decided to deliver the equalized waste to the city treatment plant at three different rates of flow: the highest flow rate corresponded to the time when the greatest amount of sewage was reaching the plant, and vice versa. This gave a more constant dilution of the mill's waste with domestic sewage.

By-Product Recovery

"By-product recovery" is the utopian aspect of industrial-waste treatment, the one phase of the entire problem that may lead to economic gain. Yet many consultants deprecate this approach to the solution of waste problems. Their attitude is based mainly on statistics concerning the low percentage of successful by-products developed from waste salvage. However, any use of waste materials obviously eliminates at least some of the waste that eventually must be disposed of, and the search for by-products should be encouraged if only because it provides management with a clearer insight into processing and waste problems. All waste contains by-products, the exhausted materials used in the process. Because some wastes are very difficult to treat at low cost, it is advisable for the industrial managers concerned to consider the possibility of building a recovery plant that will produce a marketable by-product while solving a troublesome waste problem. There are many examples of positive results from adapting waste-treatment procedures to by-product recovery.

Metal-plating industries use ion exchangers to recover phosphoric acid, copper, nickel, and chromium from plating solutions. The de-ionized water, without any further treatment, is ideal for boiler-feed requirements. For final recovery of valuable chromium, copper, and nickel, companies use vacuum evaporation of the concentrated plating solutions. A nickel-wire plating plant, faced with a nickel shortage, made the plating waste alkaline with soda ash and precipitated nickel as the carbonate, and then dried the sludge and treated it to recover the nickel. A silver-plating plant spent about $120,000 a year on waste treatment, of which $60,000 was returned as credit for silver recovered from the waste. The electrical industry recovered silver, gold, and (as by-products) water, valuable metals, and acids. Plants such as Scotscraft, Inc. reported the recovery and reuse of by-product cyanide from plating wastes. A system of evaporation is used here to result in an overall cost saving.

Specialty paper mills, with the aid of multiple-effect evaporators, recover caustic soda from cooking liquors. Chemical plants spray dilute waste acids into hot, lead-lined, brick-faced towers to concentrate the acids for reuse. Pharmaceutical houses recover molds by drying the cake from vacuum filters or evaporating spent broth in multiple-effect evaporators. Distilleries screen the “slop” and thicken it for by-product use. Yeast factories evaporate a portion of their waste and sell the residue for cattle feed.

Even sewage plants have entered the by-product business. Methane gas from sewage digesters is commonly used for heat and power, and some cities make fertilizers and vitamin constituents from digested and dried sewage sludges. The sewage plant in Bradford, England, recovers grease by cracking with sulfuric acid and precipitating with alum iron salts.

Classic examples of multiple usages of waste are the sulfite waste-liquor by-products from paper mills. They are used in fuel, road binder, cattle fodder, fertilizer, insulating compounds, boiler-water additives, and flotation agents, and in the production of alcohol and artificial vanillin. There are some 2,000 U.S. patents for products made from waste sulfite liquor.

Packinghouses and slaughterhouses recover waste blood, which is used as a binder in laminated wood products and in the manufacturing of glue; they also sell waste greases to rendering plants.

The dairy industry treats skim milk with dilute acid to manufacture casein. Casein manufacturers in turn use their waste to precipitate albumin. The resulting albumin waste is used in the crystallization of milk sugar, and the residue from this process is used as poultry feed. Calcium and sodium lactate are also produced from skim milk, and dried and evaporated buttermilk is used for chicken feed. It is even rumored that chocolate ice cream originated as a by-product of the dairy industry.

Some companies, such as rendering plants, are in business primarily to develop by-products from other plants’ waste products. Many rendering plants make feeds and fertilizers from chicken feet and feathers and recover grease, which is used to make soap.

Once a by-product is developed and put into production, it is difficult to identify the new product with a waste-treatment process. For example, when sugar is extracted from sugar cane, a thick syrupy liquid known as "blackstrap molasses" is left. This molasses used to be so cheap that it was almost given away. Today, it has many uses, with one of the best-known being in the production of commercial alcohol. People have even found a use for the cane stalks; an insulating wallboard, called Celotex, is made from it.

These are only a few of the many ways in which industry can turn waste into usable products. Although the problem of waste disposal usually persists, it is greatly lessened by the utilization of waste for by-products. In the final analysis, both economic considerations and compliance with the requirements of pollution abatement play a major role in any decisions involving by-product recovery. For a more complete treatise of by-product utilization, the reader is referred elsewhere (Nemerow 1995).

As described earlier in this chapter, the salt brine waste from the pickle processing plant offers great potential for by-product recovery. The brine waste can be electrolyzed to produce chlorine at the anode (after conversion by steam) and sodium at the cathode. The sodium can then be passed through a limestone bed and converted to soda ash. Both the chlorine and the soda ash can then be sold and reused as by-products. I have shown this more fully in Chapter 16 of this book.

Proportioning Wastes

By proportioning its discharge of concentrated wastes into the main sewer, a plant can often reduce the strength of its total waste to the point at which it will need a minimum of final treatment or will cause the least damage to the stream or treatment plant. It may prove less costly to proportion one small but concentrated waste into the main flow, according to the rate of the main flow, than to equalize the entire waste of the plant in order to reduce the strength.

Monitoring Waste Streams

Sophistication in plant control should include that of wastewater controls. Remote sensing devices that enable the operator to stop, reduce, or redirect the flow from any process when its concentration of contaminants exceeds certain limits are an excellent method of reducing waste strengths. In fact, accidental spills are often the sole cause of stream pollution or malfunctioning of treatment plants and these can be controlled, and often eliminated completely, if all significant sources of waste are monitored.

Accidental Spills

Accidental discharges of significant process solutions represent one of the most severe pollution hazards. Because many accidental discharges go unobserved and are usually small in volume, they should be given special attention by the waste engineer. However, it is almost impossible to prevent every potential accident from occurring.

I would like to point out that all so-called *accidental spills* are actually not completely preventable and, therefore, cannot (in truth) really be called *accidents*. At some time, and under some circumstances, the so-called accidental spill will become a reality. Therefore, the environmental engineer must design for such spills with "backup" prevention plans.

There are some measures that can be taken to reduce the likelihood of accidents and severity when and if they occur. Some suggestions for general use include the following:

1. Make certain that all pipelines and valves in the plant are clearly identified.
2. Allow only certain designated and knowledgeable persons to operate these valves.
3. Install indicators and warning systems for leaks and spills.
4. Install double-wall tanks.
5. Provide for detention of spilled wastewater in holding basins or lagoons until proper waste treatment can be accomplished.
6. Monitor all effluents—quantity and quality—to provide a positive public record, if necessary.
7. Establish a regular maintenance program of all pollution-abatement equipment and all production equipment that may result in a liquid discharge to the sewer.

Example of Twentieth-Century Practice of Contaminant Concentration Reduction

Goldfield (1980) found and reported that although there was little difference obtained between general plant ventilation and local exhaust systems, five procedures could be used to lessen the contaminant concentration of asbestos to the Environmental Protection Agency–required standards of 0.5–0.1 fibers/cm^3:

1. Improve enclosure of dust sources
2. Increase the amount and effectiveness of local exhaust ventilation
3. Improve housekeeping
4. Improve work practices
5. Change processes and equipment

Although Goldfield's recommendations apply primarily to inside air contaminant concentration reduction, they could also be easily applied to liquid waste concentration reduction.

Review Questions

1. What do we mean by strength reduction? Why should we use it?
2. Give an example of how a process change can reduce the strength of wastewater.

3. Give a classic example of an equipment modification to reduce the strength of wastewater.
4. How does segregation reduce the strength of the wastewater? Give an example.
5. What do we mean by equalization to reduce the strength of wastewater?
6. When is it profitable to install by-product recovery? How does this help in strength reduction?
7. Give two examples of by-product recovery by industry.
8. How can proportioning industrial waste reduce its strength?
9. What advantage is gained by installing modern methods of monitoring waste contaminants as far as strength reduction is concerned?

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