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REFERENCE DATA SHEET FOR CHEMICAL AND ENZYMATIC DRAIN CLEANERS

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POTENTIAL PROBLEM AREAS

- Chemical burns
- Dispensing methods
- Chemical reactions producing heat, gas eruptions, and/or toxic gases
- Product labeling and packaging
- Selection of protective methods
- Piping/fixture failures
- Proper maintenance

INTRODUCTION

Chemical and enzymatic drain cleaners are often added to plumbing systems to remove an obstruction or restriction, or to prevent and/or inhibit their formation. These blockages are often the result of an accumulation of human wastes, hair, paper products, grease, soap, and other foreign materials. Such materials are normally deposited in drains, pipes, and sewer lines, but the design of piping systems, the quantity of material(s) introduced into the line, and flow problems allow the occurrence of blockages.

Chemical and enzymatic drain cleaners have the appeal of being potentially easy to use, quick in their degradation of the blockage, and often are less expensive than mechanical drain cleaning equipment. Chemical cleaners work via their reactive chemical nature; enzymatic cleaners work via slower biological/digestive type reactions. Because of their chemical reactivity, coupled with the often unknown contents and configurations of plumbing systems, improper application of chemical drain cleaners can result in unexpected chemical reactions, splashes, and other effects which may result in personal injury and/or property damage.

CLASSIFICATIONS

Drain cleaners may be categorized into four major groups, which include:

- **Acids** (e.g., sulfuric acid, hydrochloric acid, ...)
- **Oxidizers** (e.g., sodium hypochlorite, ...)
- **Caustics** (e.g., caustic soda, lye, sodium hydroxide, ...)
- **Enzymatic** (e.g., organisms or biochemicals which consume or digest particular waste materials)

MECHANISMS

Acid Drain Cleaners

An acid is generally defined as **any substance that increases the concentration of hydronium ion ([H_3O+]) in solution**.[1] For example, hydrogen chloride gas when dissolved in water will react with the water to form hydronium ions; aqueous solutions of hydrogen chloride are therefore referred to as *hydrochloric acid*. Acid drain cleaners work via chemical reaction between the hydronium ion and the blockage material(s) and liberation of heat as the solution is diluted by water in the pipes (or, "heat of solution"). Reactions will occur based on:

- the chemical composition of the blockage;
- the electromotive potential for the reaction;
- the thermodynamic properties (energy changes) associated with the reaction; and
- the physical conditions associated with the reaction.

The hydronium ions may act on the blockage materials in "displacement" reactions (e.g., formation of precipitates and/or gases), neutralization, or by oxidation-reduction reactions (a change in the oxidation states of the elemental components of the reactants).[2] The heat generated is usually sufficient to locally liquefy congealed grease. Therefore, to be effective, acid drain cleaners should provide sufficient quantities of hydronium ion, the blockage material(s) should be mutually reactive with the hydronium ions, and the physical conditions should favor the reaction.

An indication of the measure of the concentration of hydronium ions is an acid's pH. Acidic pH values range from "zero" (highly acidic) to "seven" (neutral). The pH values of some common liquids are summarized in Table 1. Lower pH values indicate higher concentrations of hydronium ions and greater potential for vigorous reactions, depending upon the chemical composition of the blockage materials. An increase in the pH value by exactly one unit corresponds to a ten-fold increase in the concentration of hydronium ions (because of the logarithmic relationship of pH to concentration). The pH of a diluted acid is not directly proportional to the original concentration of hydronium ions over all possible dilutions. For example, a given volume of 85% concentration of a strong acid diluted by an equal volume of water will not result in a significant change in the pH value. This phenomenon is dependent on the ionization potential (how completely hydronium ions are produced) of the acid. Repeated dilutions with water will result in pH values approaching neutrality (pH=7).

LIQUID	pH
Stomach Acid	1.2 - 1.4
Lemon Juice	2.2 - 2.4
Vinegar	3.0
Beer	4 - 5
Urine (Human)	4.8 - 8.4
Milk (Bovine)	6.3 - 6.6
Saliva (Human)	6.5 - 7.5
Drinking Water	6.5 - 8.0
Blood (Human)	7.3 - 7.5
Sea Water	8.3
Milk of Magnesia	10.6 - 10.7

Table 1. pH of Common Liquids

Caustic Drain Cleaners

A caustic, or base is generally defined as **any substance that increases the concentration of hydroxide ion ([OH-]) in aqueous solutions.**[3] Caustic drain cleaners react in a similar method as acid drain cleaners, except hydroxide ions provide the driving mechanism for the reaction. The term "alkalinity" is used to describe the degree of caustic properties associated with the solution. In addition to the mechanisms associated with acid drain cleaners, the alkaline chemical converts grease into a water-soluble soap-like material.[4]

An indication of the measure of the concentration of hydroxide ions is a caustic's pOH. Caustic pH values range from "seven" (neutral) to "fourteen" (highly caustic). Higher pH values indicate higher concentrations of hydroxide ions and greater potential for vigorous reaction, depending upon the chemical composition of the blockage materials. The pOH and pH values are related in that their sum is equal to fourteen. **Table 2** depicts the relationship between hydronium ion concentration, hydroxide ion concentration, pH, and pOH.

Caustic drain cleaners are commercially prepared in both aqueous and granular forms. Aqueous solutions are usually composed of dissolved sodium hydroxide, and are therefore denser than water. Granular forms are usually composed of sodium hydroxide and often contain aluminum particles. These aluminum particles react with water to liberate small quantities of hydrogen gas; this reaction liberates more heat and adds force to the unblocking effect of the drain cleaner.[5] Solid sodium hydroxide adsorbs moisture (or, is "hygroscopic") and therefore may create its own blockage by forming a solid mass before it dissolves in the water retained in the piping system. Caustic drain cleaners should be placed in close proximity to the blockage material and must be chemically reactive with the blockage material to perform satisfactorily.

SOLUTION NO.	**1**	**2**	**3**	**4**	**5**	**6**	**7**
$[H_3O^+]$	10^{0}	10^{-3}	10^{-6}	10^{-7}	10^{-8}	10^{-11}	10^{-14}
$[OH^-]$	10^{-14}	10^{-11}	10^{-8}	10^{-7}	10^{-6}	10^{-3}	10^{0}
pH	0	3	6	7	8	11	14
pOH	14	11	8	7	6	3	0
Classification	Acidic			Neutral	Alkaline		

Table 2. Relationships between $[H_3O^+]$, $[OH^-]$, pH and pOH in Aqueous Solutions

Oxidizing Drain Cleaners

Oxidation (the loss of electrons) and reduction (the gain of electrons) are associated reactions; generally, whenever one substance loses electrons, another substance picks them up. An oxidizing agent is defined as **the agent which acquires electrons and becomes reduced**, while a reducing agent is **the agent which loses electrons and becomes oxidized**. [6] Oxidizing agents include nitrates, chlorates, perchlorates, hypochlorites and peroxides. Cellulosic and other organic compounds composing the blockage material(s) may act as reducing agents in contactwith the oxidizing material and can react vigorously at ambient temperatures. This oxidation-reduction reaction may potentially liberate heat and gases. Oxidizing materials such as sodium hypochlorite are often added to the formulation of caustic drain cleaners to enhance performance.

Enzymatic Drain Cleaners

Enzymatic drain cleaners utilize biological/enzymatic forms of chemical reactions to "metabolize" materials in the blockage and therefore clear the blockage. These reactions generally are:

- much slower than the corresponding acid, alkaline or oxidation-reduction chemical reactions;
- limited to reactions with organic materials; and
- not producers of significant thermal effects.

Enzymatic drain cleaners usually contain dried products consisting of enzyme preparations, bacterial cultures, and fillers. They are noncorrosive and presumably nonpathogenic, although past surveys have indicated the presence of salmonellae in these drain cleaners. [7] Many enzymatic drain cleaners originated in the biological treatment industry (e.g., septic tank treatment, waste water treatment) and have only recently entered the consumer market place. Past formulations were developed to liberate gases (such as carbon dioxide); the effervescent action allowed the active enzyme to more effectively penetrate the blockage. [8] Recent formulations of enzymatic drain cleaners have been developed to better treat hair and cellulosic (paper) blockages. Generally, chemicals contained in water soluble polymeric beads decompose the clogging material into chemical units more suitable to enzymatic action. [9,10] Enzymatic drain cleaners tend to have a short shelf-life which may be attributed to enzymatic interaction aggravated by exposure to heat (as in shipment/transportation of the product). [11] Although enzymatic drain cleaners are noncorrosive, most labels warn of harm from swallowing, skin/eye contact, and inhalation. [12]

Implications

Removal of pipeline obstructions or restrictions may be performed by mechanical or chemical removal methods. Chemical removal methods rely upon generation of heat and reaction between the drain cleaner and blockage material(s). These reactions may be of different mechanisms, but have potential to be vigorous and liberate gases. Chemicals may cause burns, react with materials other than those in the blockage, and produce other undesirable physical effects. Chemical drain cleaners may damage plumbing and surrounding surfaces. Chemical drain cleaners are generally more dense than water and tend to sink to a lowest possible point. Enzymatic drain cleaners are less likely to acutely harm the human body by direct contact with the skin and/or eyes than chemical drain cleaners. Reformulations and introduction of slower reacting methods have reduced the potential for some hazards at the expense of the potential loss of effectiveness in dissolving the blockage material(s).

Standards

Several guidelines, standards and codes exist for the various classifications of drain cleaners or for the specific chemical constituents of the cleaners. The application of these requirements is often based on place (e.g., work place, household), method of use, and person (e.g., employee, consumer). Examples of some of the possible requirements include:

- **Occupational Safety and Health Administration (OSHA) Standards**
  29 CFR 1910.1000, "Air Contaminants," addresses work place exposures to a number of hazardous and toxic substances including hydrogen chloride gas (which could be generated from highly concentrated hydrochloric acid or reactions involving mixing drain cleaners of different chemical compositions or substitution of other household chemicals as drain cleaners), sodium hydroxide contained in caustic drain cleaners, and sulfuric acid mists.

- **Consumer Product Safety Commission (CPSC) Standards**
  16 CFR 1700.14, "Substances Requiring Special Packaging," provides guidelines for the packaging of household chemicals containing ten percent or more (by weight) of sodium hydroxide, potassium hydroxide, or sulfuric acid.

- **The Association of Chemical Producers (ACP)**
  "Minimum Standards for Sulfuric Acid Drain Cleaners" addresses labeling, packaging, formulation, and other concerns related to sulfuric acid drain cleaner products.

- **The National Institute for Occupational Safety and Health (NIOSH)**
  The "Occupational Health Guideline for Sodium Hydroxide," "Occupational Health Guideline for Sulfuric Acid," and "NIOSH Recommended Standard for Occupational Exposure to Sodium Hydroxide" address work place usage and exposures, labeling and warnings, personnel protective equipment, and work practices to reduce exposures to these chemicals.

- **The American National Standards Institute, Inc. (ANSI)**
  "American National Standard for Hazardous Industrial Chemicals - Precautionary Labeling," ANSI Z129.1-1988, addresses the preparation of precautionary labeling of hazardous chemicals used under industrial occupational settings.

Reactions And Incompatibilities

The heat liberated by chemical drain cleaners may soften plastic (PVC) pipes. Combined heat and chemical reaction may damage old, corroded pipes. Acid drain cleaners can corrode or etch stainless steel, damage aluminum fixtures, and (by heat of solution) may crack porcelain. If a chemical drain cleaner does not remove the obstruction in the piping system, the chemical may remain unreacted in the piping system. Users occasionally attempt to clear a blockage by using more than one product. The introduction of acid drain cleaners into pipes containing caustic drain cleaners may result in vigorous acid-base neutralization reactions. These reactions generally result in the formation of a salt and water, but may generate extreme heat and, consequently, the liquids may spatter or erupt from the drain. Dilution of concentrated caustics and acids may also generate heat. This "heat of solution" may be considerable and variable, depending on the initial and final solution concentrations. If the chemical remains unreacted in the piping system, persons subsequently attempting to clear the blockage by mechanical means may unknowingly have potential of exposure to the chemical.

The addition of water to a concentrated caustic or acid may also result in boiling and spattering of the resulting solution; if the *caustic or acid* is slowly and carefully *added to water*, this effect is minimized. Standards often recommend using the term "concentrated" for aqueous solutions as a warning for potential health effects or injuries to tissue. However, chemical texts often use the same term for nearly pure solutions.

Reactions which generate gases may result in pressure buildup and possible eruptions because of volumetric differences between liquids and gases. The mixing of caustic acid drain cleaners containing sodium hypochlorite with other household chemicals may result in the generation of toxic gases such as chloramine or chlorine. The oxidation of organic materials may result in the formation of gases such as carbon dioxide, hydrogen, and/or organic gases. Carbonates in concrete and acid drain cleaners may react to liberate carbon dioxide gas. Enzymatic treatments generally require at least one overnight application, during which the drain cannot be used. Most treatments require additional applications in order to establish a colony; because bacteria are regularly washed out as the drain is used, such treatments recommend monthly maintenance applications. Addition of bleach, disinfectants, solvents, or other chemicals may be harmful to the established bacterial colony. [12]

Implications

Chemical and enzymatic drain cleaners are potentially dangerous to use. They are reactive with human tissue in a similar manner as to the organic materials in drain blockages. Hazardous and toxic gases may be generated, as well as spattering and/or eruptions. Standards exist addressing these potential hazards with recommendations for proper and safe use, packaging and labeling recommendations, and personal protection recommendations. Recommendations have been made to use preventive methods such as avoiding pouring grease down drains; using strainers to trap food, hair, and other articles; regular biological/enzymatic treatments; and/or, pouring hot water down the drain weekly to keep the drain free flowing. (The water should be poured directly into the drain rather than in the basin, so as to avoid cracking of porcelain fixtures). If a drain requires cleaning, consumer advocates recommend the use of mechanical devices, followed by removal and cleaning of traps and cleanout plugs. Chemical cleaners are recommended only as a last resort; if the chemical drain cleaner fails to work, a professional should be contacted and the situation should be explained. [13,14]

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