SRI International

PROFILE OF RELEASE AND EXPOSURE FOR CHEMICALS USED IN PROCESSING ORES AND MINERALS

Final Report

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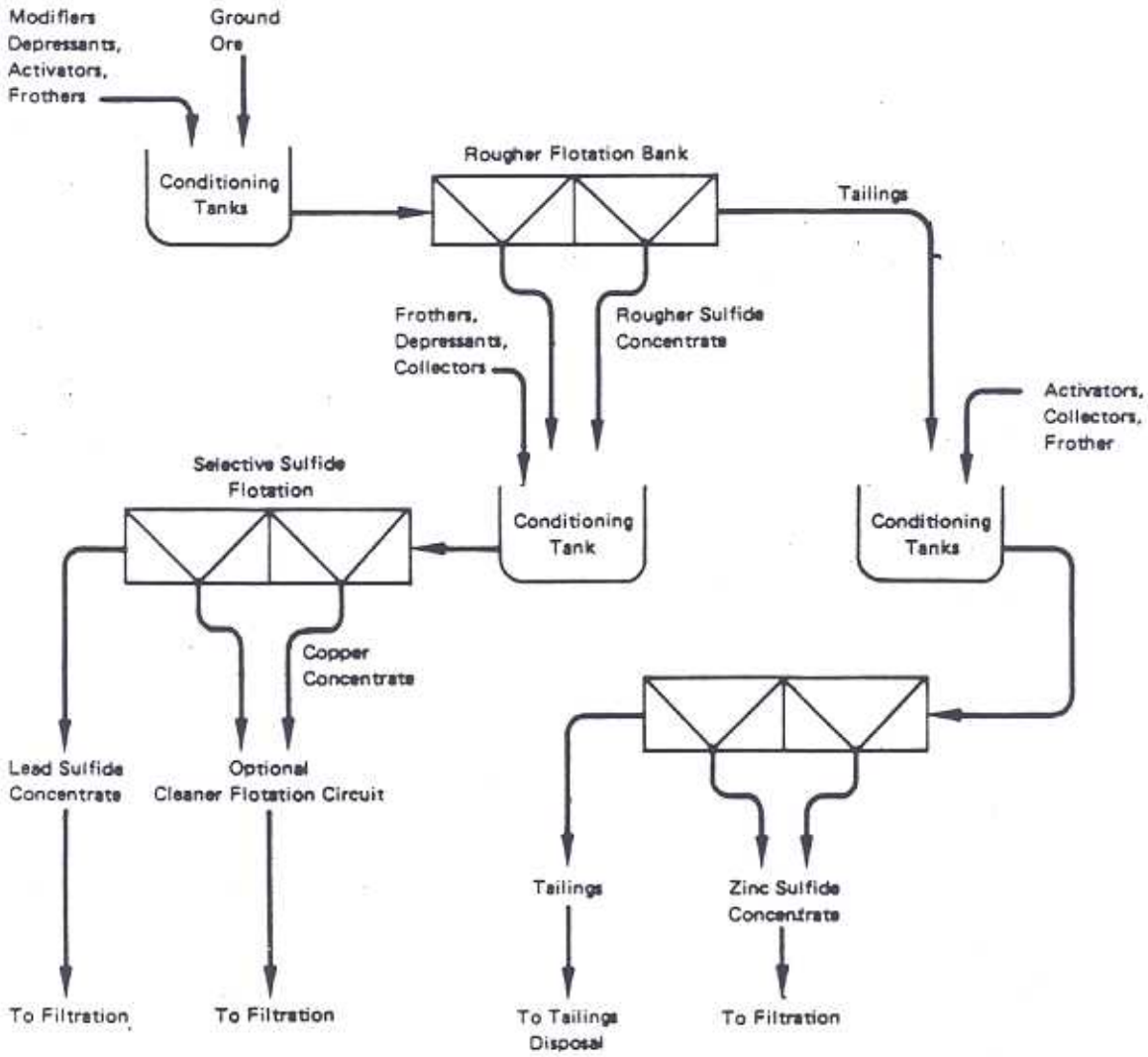

SOURCE: SRI International

FIGURE 25 GENERALIZED FLOTATION FLOW SHEET FOR SULFIDE ORES

Table 34

FLOTATION EMISSIONS

Substance	Flotation Feed (ppm)	Concentrate Fraction (ppm)	Tailings Fraction (ppm)	Airborne Emissions (lb/ton feed)
Collector	8-300	64-2575	1-40	10^{-6}-$4x10^{-5}$
Frother	1-75	7-700	1-7	$7x10^{-7}$-$7x10^{-5}$

Source: SRI International

- Reagent distribution--virtually all the collector is attached to mineral particles reporting to the concentrate, and all of the frother is bound to aeration bubbles; 10% of the droplets ejected from the froth remain airborne, and therefore 90% of the frother reports to the concentrate. It is understood that 100% of the bubbles in the froth break up.

- Aeration and reagent dosage rates--collector dosage ranges from 0.05-2 lb per ton of flotation feed, and frother dosages from 0.005-0.5 lb/ton. Aeration rates are in the range of 500-5,000 ft^3 per minute per ton of flotation feed.

- Physicochemical properties--frothers have vapor pressures under ambient temperature in the range of 0.5 mm Hg, which corresponds to the calculated vapor pressure for MIBC. Raoult's law applies for calculating solute vapor pressures. Aerosol emissions were based on experimental results regarding bursting bubbles.*

The emission estimates of Table 34 result from the above simplifying assumptions and mass balance calculations that reflect the block diagram of Figure 29 and that are summarized in Table 35.

Note that the results of Table 34 above do not include estimates for solid particulate emissions. Under the assumptions made, such particulate emissions (resulting from bursting bubbles) amount to about 0.002 lb/ton of material treated in flotation. Note also that frother air emissions average at less than 5×10^{-6} lb/ton, and this represents only 4% of total frother emissions. Furthermore, calculations adopting different vapor pressure assumptions, have shown that the vapor pressure of the frother does not greatly affect the emission rate until it exceeds about 2 mm Hg. Within this range, the

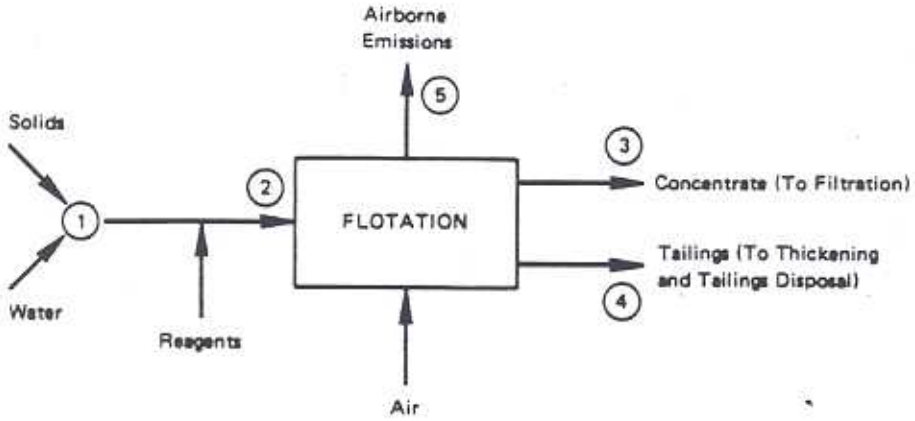

FIGURE 29 SCHEMATIC DIAGRAM OF FLOTATION PROCESS

Table 35

MASS BALANCE OF FLOTATION PROCESS

	1	2	3	4	5
Units		ppm	ppm	ppm	lb/ton
Solids	--	25%	15%	26%	0.002
Reagents					
Collector	0.05-2.0	8-300	64-2,575	1-40	10^{-6}-$4 \cdot 10^{-5}$
Frother	0.005-0.5	1-75	7-7,000	1-7	$7 \cdot 10^{-7}$-$7 \cdot 10^{-5}$

emission rate of frother, expressed in pounds per ton of ore processed, can be approximated by the following formula:

$$\text{Emission rate} = (\text{frother dosage rate, in lb/ton})(1{\cdot}4{\cdot}10^{-4})^{3} .$$

For frothers having high vapor pressures--that is, exceeding 2 mm Hg--the estimates made with the above formula should be doubled. It should be stressed also that because of the aerosol and vaporization mechanism(s) in flotation, the emission factors estimated above apply to most conditioners having low vapor pressure and high water solubility.

As previously mentioned, airborne emissions of collector are caused by its adsorption onto mineral surfaces and subsequent emission of concentrate particulates. Less than 1% is emitted by vapor saturation mechanisms. The emission rate of collectors and other substances that similarly attach to mineral particles (activators, depressants) can be estimated by the following formula, again expressing emission in pounds per ton of material treated:

$$\text{Emission rate} = (\text{collector dosage rate, in lb/ton})(1{\cdot}6{\cdot}10^{-5}) .$$

When these airborne emission estimates are applied, the broad range of operating conditions in flotation and their influence over the assumptions adopted above should be recognized. Although SRI's assumptions reflect operating conditions encountered in numerous industrial plants, significant differences exist among individual mills, particularly with respect to ore grade, solids concentration in the various flotation streams, and in the recovery of valuable minerals. For example, copper ores in the United States seldom contain more than 0.7% copper, and occasionally the flotation process is applied to an ore fraction that has already been treated by flotation. These differences will yield different values than those given in Table 33. Nevertheless, because the principal parameters influencing airborne emissions are aeration and reagent dosages, and these two parameters exhibit the greatest variability in the process, SRI believes that the variance encountered in individual plant practices are covered in the range of SRI's estimates.

Waterborne Emissions in Flotation--Waterborne emissions in flotation include collectors, frothers, activators, depressants, and miscellaneous modifying agents that report to either the concentrate or the tailing process streams. Collectors and frothers, as well as most of these other reagents, are primarily associated with the concentrate stream although minor amounts remain dissolved in the tailings stream.

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*Pahren, H., and W. Jakubowski, eds, "Wastewater Aerosols and Disease," EPA-600/0-80-028, December, 1980.

In standard practice, concentrates and tailings are subject to dewatering prior to final disposal by filtration in the case of most concentrates and by sedimentation thickening in the case of tailings. Accordingly, because aqueous effluents are not released to the environment during flotation but proceed to subsequent processing stages, water emissions are estimated under the appropriate description involving these processes. However, to help understand how subsequent estimates are derived, information regarding water usage rates in flotation is summarized in Table 36.

Table 36

ESTIMATED WATER USAGE RATES IN FLOTATION

Approximate Cell Volume (ft^3)	Cell Capacity (tons/day)	Water Usage (gpm)
20	40	55
60	100	150
100	160	250
300	500	700
500	830	1050
1000	1600	1200

Source: SRI International

Dewatering

Dewatering is the separation of solids from the water in a mixture. Dewatering of coarse particles involves water drainage based on gravitational principles using stationary or mechanical equipment such as screens, cone dewaterers, classifiers, scrapers, and hydrocyclones. Coarse dewatering is normally part of the earlier stages in ore processing and seldom of the stages following concentration. Such dewatering takes place in conjunction with size classification operations, normally those associated with comminution. As noted earlier (see Comminution subsection), the use of chemicals in these operations is not widespread. Moreover, because the primary aim of such operations is not dewatering but size classification, emissions from coarse dewatering are negligible at this stage . . . most process streams that potentially contain chemicals proceed to concentration, at which stage the bulk of the solids is no longer coarse, but consists of finely divided mineral particulates liberated from one another.

In contrast, dewatering of fine particulates is an area of primary concern because most chemical substances used in ore processing are carried to this stage. Fine dewatering can be accomplished in several ways, but the most commonly used methods for both mill concentrates and tailings are thickening and filtration. Both methods warrant description.

Thickening

Thickening is the process of removing water from a relatively dilute suspension containing ultrafine particles. Thickening is normally based on sedimentation principles. Because solids at this processing stage are sufficiently fine that minor currents or turbulence can maintain them in suspension, effective separation of solids from suspension can be effected only by bringing the aqueous media substantially to rest and by allowing time for the solid particles to settle. Although sedimentation concepts are common, their specific mode of application varies, depending on the type of equipment used and on upstream operations.

For example, thickening is frequently used in hydrometallurgical applications to partially separate leached solids from pregnant solutions containing values in solution. A specific method of thickening for such types of application is known as countercurrent decantation (CCD), extensively used in the extraction of uranium and oxide copper, during which process the valuable metals must be kept in solutions while waste solids are removed. CCD is a continuous washing procedure in which the feed slurry advances through a series of thickener tanks while clarified water is pumped countercurrent to the slurry flow. The diluted slurry in each tank is mixed by agitators. When the slurry (underflow) reaches the end of the series of thickeners, it is high in solids and low in dissolved values. The countercurrent water (overflow), however, is low in solids but high in values. The high solid slurry fraction is sand-filtered, and the acid water is returned to the back section and the solid wastes go to the tailings disposal area. The overflow pregnant solution moves to the ion exchange stage for the stripping of values. This type of fine dewatering has already been considered in the previous subsection dealing with solution mining and, in particular, with solvent extractions.

Other types of thickening operations, more appropriate for dewatering concentrates and tailings, are gravity and centrifugal thickening. Gravity thickeners are settling tanks that are divided into four zones: a slurry inlet, a water outlet, a sludge zone to receive and remove settled materials, and a settling area to provide tank volume for settling. Figures 30 and 31 depict this type of equipment. If a sedimentation unit is being used for removing flocculated solids, it is important that the velocity of the influent channel be kept low. They may be designed for either batch or continuous operation.

Table 37

THICKENING EMISSION RATES

	① Flocculant Addition (lb/ton)	② Thickener Input Stream (ppm)	③ Thickener Underflow (ppm)	④ Thickener Overflow (ppm)
Solids (%)	--	26	60	2.5
Reagents:				
Collector	--	1-40	1	2-70
Frother	--	1-7	1-3	1-9
Flocculant	0.002-0.08	1-10	1-25	1

Source: SRI International

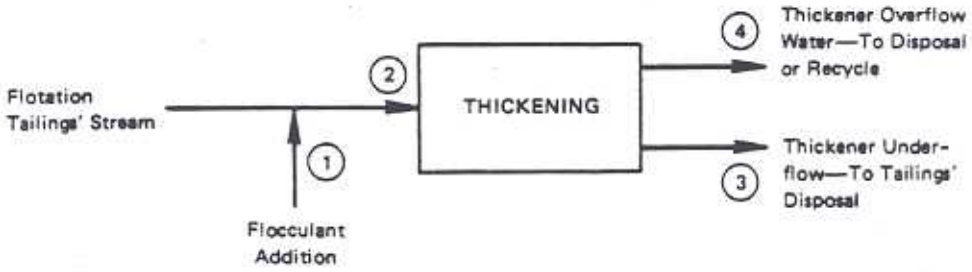

FIGURE 32 BLOCK DIAGRAM OF THICKENING PROCESS

- Approximately 95% of the solids are recovered in the thickener underflow, and this product contains about 60% solids. This results in a thickener overflow that is essentially water and contains only 2.5% solids. Further, the feed input to the thickener averages some 26% solids and may contain flocculant dosages in the range of 0.002-0.08 lb per ton of solids.

As in the case of other extractive processes, the assumptions leading to the emission estimates in Table 37 are reasonably representative of many industrial conditions. Nevertheless, they

cannot include the fairly broad range of actual operating conditions that are known to occur in industry, particularly with respect to variations in the solids concentrations at input and output points, or variations in solids recovery. Such variations, however, result in differences in emission rates that are notably less significant than those due to reagent dosage and included in Table 37.

Filtration

Filtration is used to separate liquids from solids more completely than settling alone. It is used principally in dewatering flotation concentrates and tailings to clarify decanted pregnant solution, or to collect precipitates, or in hydrometallurgical processes to remove pregnant solution from leached solids.

Of the various types of filters, the most common is the vacuum filter. These may be horizontally mounted rotating drums or rotating disks, the lower segment of which is immersed in pulp in a tank. Feed pulp is kept in suspension by rotary agitators. Pumps suck the liquid through the filter but leave the caked solids. Just before the drum or disk reaches the tank again, the vacuum shuts off, pressurized air is applied to dislodge the filter cake, or alternatively scrapers remove the filter cake into a discharge chute. Figures 33 and 34 illustrate examples of this type of equipment.

For certain high-extraction applications, such as gold or uranium, horizontal belt filters may be used. Here the slurry is fed onto a continuous belt, and drying takes place as the belt moves from the feed point to the discharge point. The photograph of Figure 35 depicts a typical horizontal belt filter.

In addition to the above, a third type of filtration equipment, filter-thickeners, combines some elements of filtration with those of thickening. Filter thickeners depend primarily on filtration to separate liquid from solid. They differ from filters in that the solid deposit on the filtering septum is not normally exposed to air drying, but is dropped in the presence of the pulp feed, settling rapidly because of aggregation. They are particularly useful for thickening, washing, and leaching materials that do not readily settle from a suspending fluid. A filter thickener is usually a deep tank with a pulp feed, a sludge-discharge connection, and several submerged filter elements connected to a vacuum. Filtration and droppage of cake are alternated automatically at short intervals, the wet cake being forced off by a counterflow of low-pressure air or water introduced from behind the filter. The dropped cake is removed from the bottom of the tank by pump as a thick sludge. Despite sedimentation phenomena, filter thickeners resemble drum and disk filters, not just visually but environmentally as well, because the way most of the airborne emissions occur is identical to that of conventional filters.

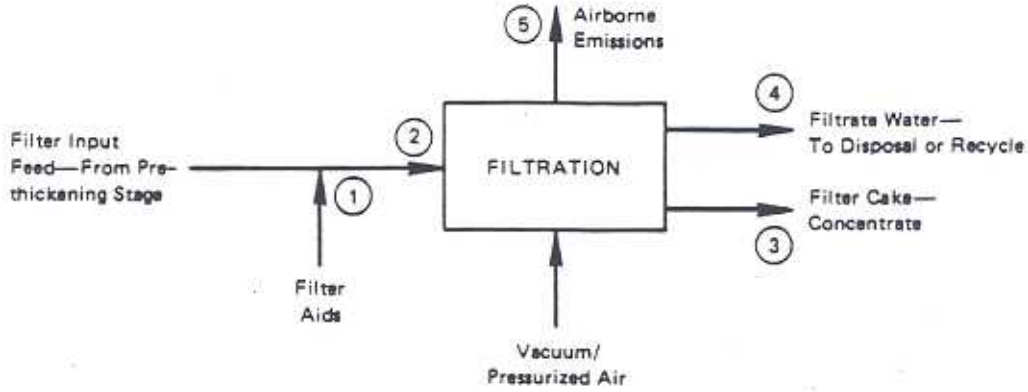

FIGURE 36 BLOCK DIAGRAM OF FILTRATION PROCESS

Table 38

EMISSION ESTIMATES FOR FILTRATION

	① Filter Aid Addition (lb/ton	② Filter Feed (ppm)	③ Filter Cake (ppm)	④ Filtrate Water (ppm)	⑤ Airborne Emissions (lb/ton)
Solids (%)	--	15	85	0	0.1
Collectors	--	64-2575	354-14,166	1	$0-5\cdot10^{-10}$
Frothers	--	7-700	1-83	8-80	$0-5\cdot10^{-9}$
Filter aids	0.005-0.2	1-15	2-83	1	$0-2\cdot10^{-9}$

Source: SRI International