of **acid rain**. The enzyme responsible for converting the urea in urine to ammonia is found in fecal matter. If the urine and the fecal matter are kept separate the enzymatic action will not occur. While keeping the urine and fecal matter completely separate is impossible, ammonia production can be controlled and kept to a minimum through source separation.

a. Belt Separation

Belt separation is the most common type of source separation. Belts are relatively easy to integrate into existing infrastructure, especially housing with slatted floors. Swine housing often uses slatted floors for manure collection. Conveyor belts are placed beneath the slatted floor. The belt should either be concave or positioned at an angle, allowing the urine to flow into a gutter, and away from the solids dropping onto the belt. The liquids flow down the gutter by gravity and into a collection tank. The manure solids are scraped off the belt and into a separation collection area. **Figure 3.1** is a photograph of a belt system.

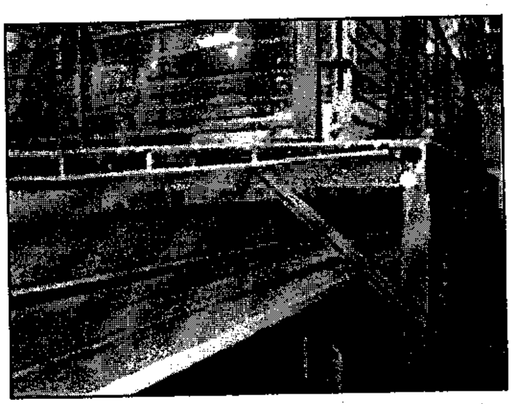

Figure 3.1: Belt system (F. Humenik, 2004).

Animal behavior should be considered during design. For instance, pigs have a tendency to defecate against the back wall of pens or against partitions between pens. This behavior will dictate the best placement of the belt. The removal of the solids from the belt should be timed to maintain workable moisture contents. In a study of belt separation in swine facilities, the feces removed in the afternoon were the wettest while the feces removed in the morning were drier. The dry matter content of the feces at the six a.m. collection was 42 to 54 percent; the fecal matter was dry to the touch, did not clump, and was stable when stored (van Kempen et al., 2003). This is because like humans, pigs sleep most of the night and do not generally urinate or defecate during that time, allowing the fecal matter on the belt to dry overnight.

Conveyor belts have been used in poultry operations for about 30 years (van Kempen et al., 2003). These belts have a life expectancy of eight to ten years, and require minimal maintenance (van Kempen et al., 2003). Belt systems are currently being integrated into swine housing and are showing similar maintenance and replacement requirements. The conveyor belts require electricity, and this continuous cost should be considered as part of the total cost during the planning process. Installation costs may be relatively low if existing slatted floors are used.

Rice and others (2003) studied belt separation of swine waste and determined that the separated solids had a moisture content of about 60 percent and the solids contained 96 percent of the total phosphorus. These solids are ideal for other treatment processes such as anaerobic digestion, soldier fly **larvae** production, and vermicomposting. The solids may also be used as lime stabilization or processed further to be used as a feed supplement. The same study showed that the urine contained 77 percent of the total nitrogen from the manure (Rice et al., 2003). The liquid can be used as a nitrogen-rich fertilizer.

Acid rain: Any form of precipitation with a pH less than 5.6, the normal pH of rain. Nitrogen oxides (NO_x) and sulfur dioxide (SO_2) released into the atmosphere, generally by anthropogenic sources, turn into acids, lowering the pH of precipitation. Acid rain is harmful to vegetation, soils, and waterbodies.

Larvae: (pl. of larva) Insects that are in the immature, worm-like stage after hatching from the egg.

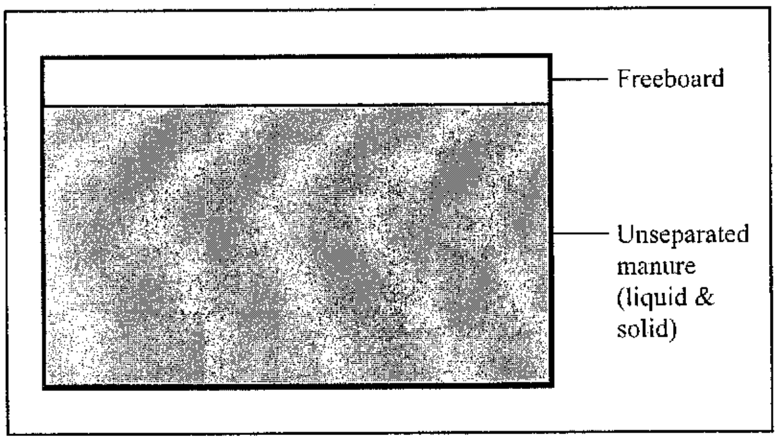

Figure 3.2: Poor settling with high solids content (J.R. Bicudo, 2001).

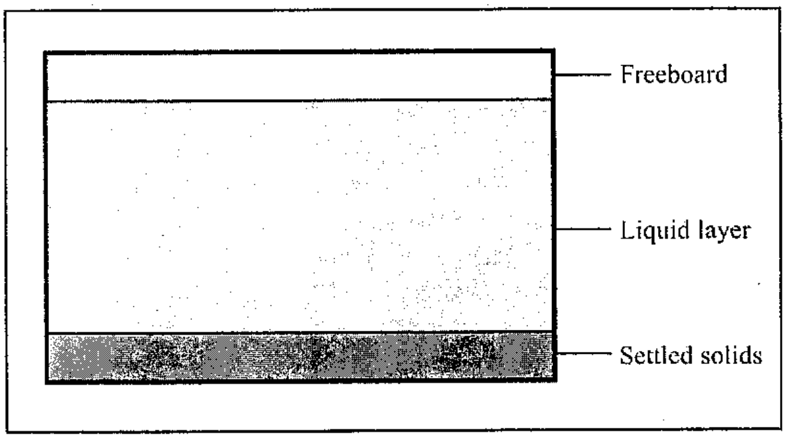

Figure 3.3: Settled solids with a liquid layer (J.R. Bicudo, 2001).

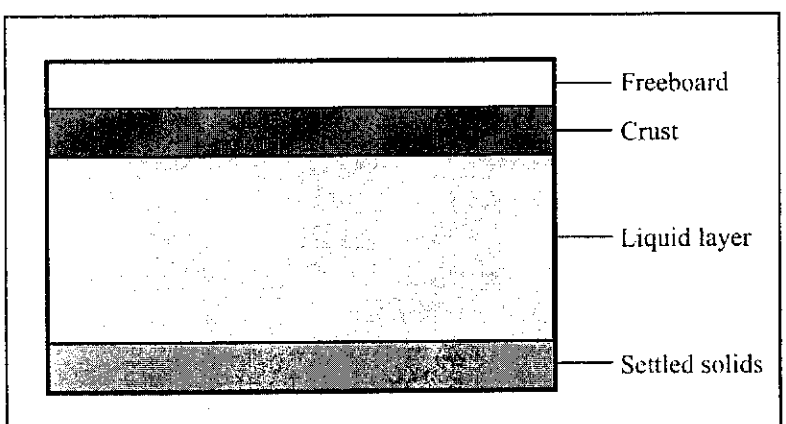

Figure 3.4: Settled solids, liquid layer, crust (J.R. Bicudo, 2001).

3.3.2 Delayed Separation

Delayed separation processes occur after the urine and the fecal matter have been mixed or diluted with flush water. There are two physical traits of the manure that determine the effectiveness of the methods used to separate the solids from the mixture. The first is the density of the solids in relation to the density of the liquid. If the solids are less dense than the liquid, they will float. Skimming devices may then be used to remove the solids. If the solids are denser than the liquid, they will sink. Gravity separation, such as settling basins, may be best suited in this case. The second characteristic is the particle size of the solids. Screening may be used to selectively remove solids of certain sizes.

There are three kinds of delayed solids separation processes—gravity, mechanical, and chemical.

a. Gravity Separation

Gravity separation, also called passive separation, uses the natural downward force of gravity to settle the denser solids from the liquid. Gravity separation partitions the nutrients and organic matter into the solid fraction.

The terms settling and sedimentation are often used interchangeably. There are three main types of settling patterns, as depicted in **figures 3.2-3.4**. The first situation usually occurs when the manure has a high concentration of solids in suspension. These suspended solids are often bedding and waste food. The second situation occurs when the solids have a greater density than that of water. Swine manure often falls into that category. The third situation is often seen with cattle manure. A crust composed of solid particles less dense than water forms on top of the liquid.

Gravity systems can be settling channels, settling basins, or settling ponds; these systems all require additional storage for the separated liquid as well as periodic removal of the settled solids. Care must be taken to prevent catastrophic spills caused by inadequate **freeboard** or from a breach of the embankments and leaching of contaminants to groundwater.

1. Settling Channel

Settling channels are wide, shallow trenches. They generally have a slightly sloping flat bottom. **Figure 3.5** is a diagram of a settling channel. The manure moves at a low velocity through the channel, allowing the solids to settle out. Settling channels can be constructed of various materials. This method of gravity separation is often found in areas with less than 63.5 centimeters (25 inches) of annual rainfall (Hartzell, 2001). **Figure 3.6** is a photograph of a settling channel.

The clarified liquid can be removed from any settling chamber in a number of ways. The first method is an overflow. With overflows, when the liquid level reaches a certain height the liquid simply flows over a small dam into a catchment basin for storage or to be pumped for recycling.

A second method is a porous dam. The liquid flows through spaces in the dam, and out to a catchment. Porous dams,

Figure 3.6: Photograph of settling channel. (P. Wright, 2004).

also called picket fence separators, can be easily constructed from wooden two by sixes or two by twelves (Bicudo, 2001). There should be two centimeter (¾ inch) spaces between the boards (Bicudo, 2001). Porous dams may make up an entire wall of the settling chamber or part of a wall.

Porous dams may also be paired with a perforated riser or pipe. In this case, the liquid flows through the dam and, when the liquid level reaches a certain height, into the perforations in the pipe. The pipe directs the liquid to a separate storage area. The riser pipe is usually made of PVC, galvanized steel, or concrete. For sizing, the rule of thumb is that the open area of the porous dam should be twice the area of the total open space in the riser pipe. The perforations in riser pipes can be 1.6 to 2.5 centimeters (5/8 to one inch) in diameter or 2.5 by 10 centimeter (one by four inch) slots. The total open space in a riser is matched to the flow rates in the settling chamber to ensure adequate retention times.

Freeboard: The vertical space between the surface of a water body and the top of the surrounding embankment.

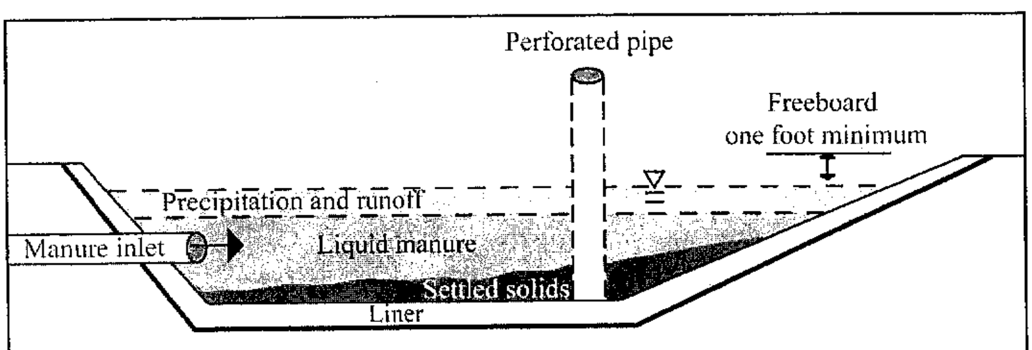

Figure 3.5: Diagram of settling channel (C. White, 2004).

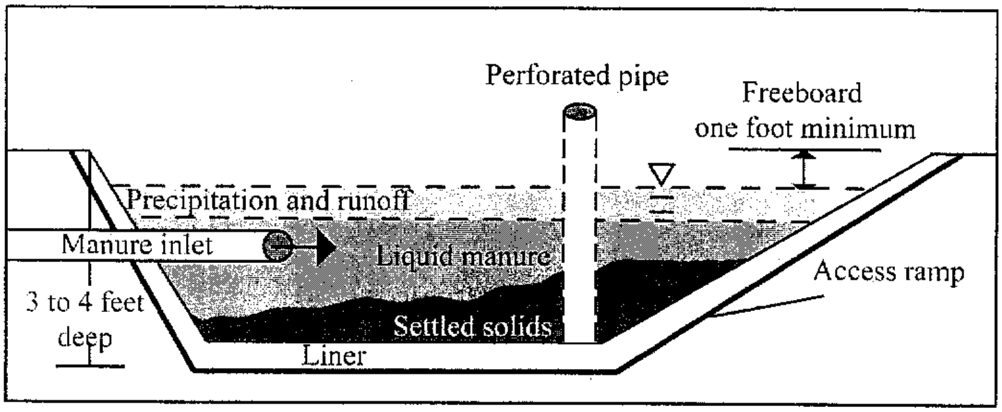

Figure 3.7: Diagram of settling basin (J.R. Bicudo, 2001).

2. Settling Basin

Settling basins are deeper than settling channels, but are not usually more than 0.9 to 1.2 meters (three to four feet) deep (Bicudo, 2001). **Figure 3.7** is a diagram of a settling basin. The basins are constructed to hold enough liquid to slow the velocity of the incoming slurry. Reducing the horizontal velocity allows the solids time to settle. In general, a shallow broad basin with a long flow path will be more effective at solid separation than a deep narrow settling basin. **Table 3.3** depicts settling basin performance while **table 3.4** depicts performance of a deeper settling tank.

Settling basins are best for continuous or at least regular wastewater flows. Settling basins are usually concrete or constructed from compacted soils paired with an impermeable liner.

Settling basins are usually found in pairs. While one basin is drained for solids removal, the other can still operate. Draining is facilitated by pumping the basin out or including a drain in the design. **Figure 3.8** is a photograph of a settling basin.

Table 3.3: Settling basin performance, results in wet basis (Adapted from Bicudo, 2001).

Manure	Input Solids	Percent Removal from Liquid					Reference
	(percent)	Solids	COD*	TKN†	N‡	TP§	
Dairy	1.1	65‖	--	40	--	--	Powers et al., 1995
Flushed dairy	3.83	55	61	24	21	--	Chastain et al., 1999
Milking parlor	0.7	27	27	24	21	--	Sweeten and Wolfe, 1994
Flushed swine	0.2	12	--	33	--	22	Westerman, 1997

* Chemical oxygen demand. † Total Kjedhal nitrogen. ‡ Organic nitrogen. § Total phosphorus. ‖ Volatile solids

Table 3.4: Performance of a settling tank with 30 minute retention time receiving 1.2 percent total solids flushed swine manure (Miner et al., 2000).

Characteristic	Performance (percent)
Total solids (TS) removal	35
Biological oxygen demand (BOD) removal	25
Total nitrogen (N) removal	15
Ammonia nitrogen removal	10
Total solids (TS) in the bottom sludge	7

3. Settling Pond

Settling ponds are longer and deeper than both settling channels and settling basins. The depth allows for months or even years of solids retention before solids removal is required. Solids are generally removed from settling ponds with excavation equipment. **Figure 3.9** is a diagram of a settling pond and **figure 3.10** is a photograph of a settling pond. The high volume capacity of settling ponds creates a situation where spills and leaks can be especially catastrophic.

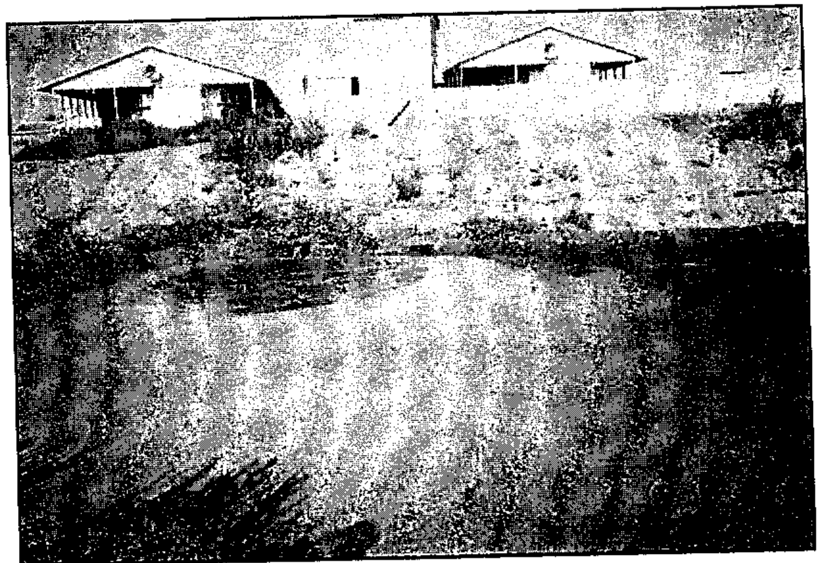

Figure 3.8: Photograph of settling basin (P. Wright, 1981).

b. Mechanical Separation

Mechanical separation relies on a combination of moving parts and gravity to separate manure solids from the waste stream, mostly utilizing the size of the solid particles to achieve separation. While mechanical processes can achieve separation faster than gravity processes, there are tradeoffs; for example, the expense of the power to drive the machinery and the maintenance required of moving gears can be high. Mechanical systems can range from the very simple to the very complicated. Mechanical systems for solids separation are sloping stationary screens, vibrating screens, screw presses, drag chain separators, roller presses, and centrifuges.

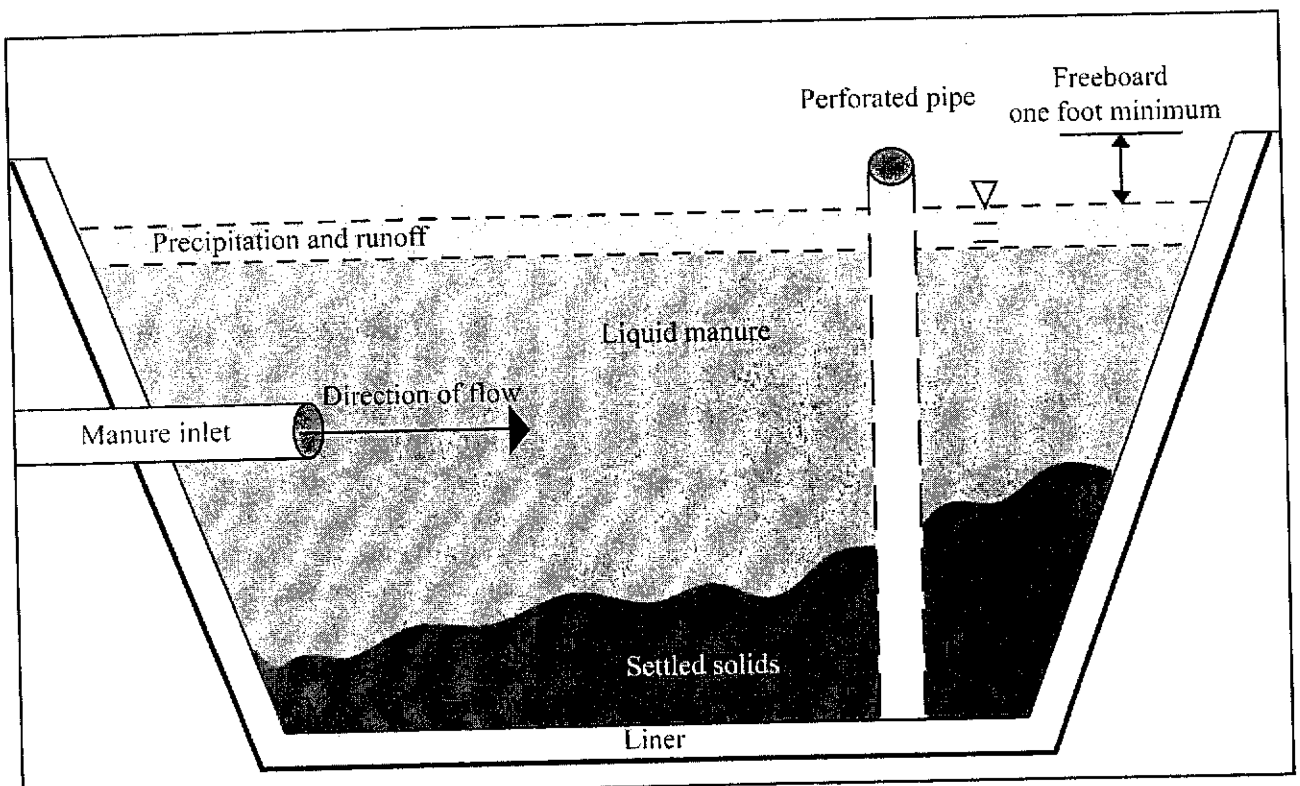

Figure 3.9: Diagram of settling pond (C. White, 2004).

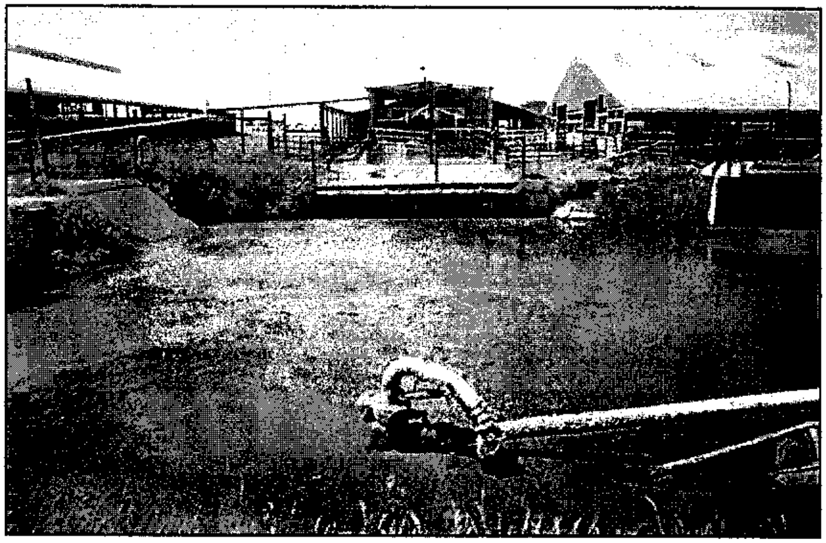

Figure 3.10: Photograph of settling pond (P. Wright, 2004).

1. Sloping Stationary Screen

Free liquid: Liquid that is not bound to solid particles.

Biomass: The total dry mass of an individual or population.

The sloping stationary screen is the most common method of mechanical solids separation. Sloping stationary screens have a simple design with a low operating cost. The slurry is deposited at the top edge of the sloping fabric screen, where the screen is virtually vertical. As the slurry moves down the slope, **free liquid** flows through the perforations. Solids remain on the screen surface. **Figure 3.11** illustrates the design of a sloping stationary screen.

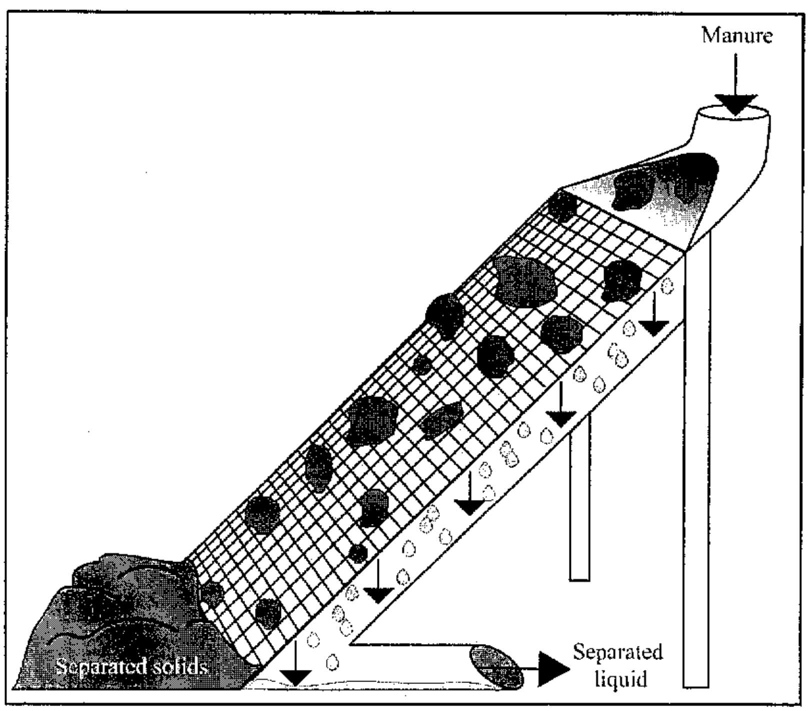

Figure 3.11: Diagram of sloping stationary screen (C. White, 2004).

While sloping screens are relatively simple to use, they still require maintenance. Bacteria can proliferate on the screen fabric, restricting the flow of liquid through the mesh. This **biomass** simply needs to be scraped off periodically. Scraping can be accomplished manually or with mechanical fittings. **Figure 3.12** is a photograph of a sloping stationary screen system.

Figure 3.12: Photograph of sloping screen (J. Robbins, 2004).

This system requires highly diluted slurries. The relationship between the efficiency and the mesh size is inverse —the efficiency of screen systems increases as the perforation size decreases. Sloping screens are best paired with another process, such as a roller press, to increase the separation efficiency. **Table 3.5** gives some performance data regarding sloping stationary screens. The values given correspond to the liquid fraction.