# SLUDGE DRYING BED DESIGN REVIEW

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Project Officer: Jon Bender

Submitted by:

James M. Montgomery, Consulting Engineers, Inc.

Pasadena, California

## INTRODUCTION

The sludge dewatering system most commonly used in small wastewater treatment facilities is the sand drying bed. Insufficient drying bed capacity can severely limit the capability to remove excess activated sludge from the biological treatment processes which, in turn, can limit the treatment process performance. Insufficient dewatering system capacity can result from inadequate estimates of sludge production from the wastewater treatment processes, inadequacies of sludge treatment processes and/or inadequacies in the design of the sludge dewatering system.

Inadequate design of sand drying bed systems is potentially one of the reasons that wastewater treatment plants experience sludge handling limitations. A survey of explicit sludge drying bed design criteria was therefore conducted to determine if sludge drying bed design is a potential problem. This report presents the results of the survey of design textbooks and manuals, published state guidelines, and technical literature for sand drying bed design criteria. The survey was limited to explicit design criteria for drying bed capacity which typically may be employed for the design of small wastewater treatment works.

## DESIGN CRITERIA

Design criteria for sludge drying beds are most often presented as explicit values expressed as per capita population equivalents. Such units of expression are typically square feet of bed area per capita. Alternate units of expression for drying bed design criteria that are encountered are pounds of solids per square foot of bed area or depth of sludge applied per year.

Necessary distinctions which are made to qualify the available design criteria are the type of sludge to be dewatered and whether the beds are exposed or covered. Exposed and covered drying conditions can be distinguished through separate design criteria or by percent reductions in the required exposed-bed are to account for the more favorable drying conditions of an enclosed installation.

Drying bed design criteria as recommended by state agencies are presented in Table 1. The open-bed capacities ranged from 1 to 2.5 sq ft/capita. Alternate units of expression were utilized by the States of Arizona (lbs/sq ft/yr) and Wyoming (ft/yr). A lack of continuity in the units of expression and the type of sludge to be dewatered, when noted, preclude detailed comparison of the reported values other than to acknowledge that general agreement exists.

The explicit drying bed design criteria obtained from design textbooks, manuals and the literature are presented as Table 2. Table 2 was prepared to illustrate the typical design criteria that are readily available to the practicing engineer. More thorough presentations covering a wider variety of sludge types and environmental conditions can be found elsewhere (U.S. EPA, 1979).

Most of the texts reviewed presented drying bed design criteria which were citations from WPCF MOP No. 8 (1959). The design criteria from this original work were calculated on the assumption of a per capita raw sludge production rate, and were confirmed to be appropriate in a 1957 study of the performance of existing plants. A range of values was originally presented because the sludge drying process is subject to several factors including rainfall, temperature, sludge drainage rate and relative humidity.

In addition to the original work of WPCF (1959), the more extensive presentation of the U.S. EPA (U.S. EPA, 1979) (U.S. EPA, 1978, 1982) cited Imhoff, et al. (1956), and an early edition of Ten States Standards (1971) when specifying values for particular regions (latitudes). Imhoff made his predictions from an assumed amount of digested sludge per capita and an assumed length of drying season and number of draws on the bed per drying season. The loading values ranged from 0.75 to 3 sq ft/capita, or 15 to 27.5 lb dry solids/sq ft/yr for open beds, to 0.75 to 1.5 sq ft/capita for enclosed beds.

Different types of sludge are represented by the range of values reported in Table 2. Digested primary plus chemical precipitate sludge requires nearly double the surface area than does primary plus digested activated sludge. This is because these sludge mixtures must lose most of the water by evaporation (Imhoff, et al., 1956).

The addition of polymer can often increase the sludge loading by 20 to 50 percent. This is because more water drains during the filling of the bed. When treated with polymer, anaerobically digested sludge can float, leaving several inches of free water underneath which quickly drains. Also, the polymer flocculant will release large amounts of free water while forming large floc, thus requiring less water to be evaporated. Polymer may also capture fine particles which could otherwise blind the drainage media (Beardsley, 1976).

Some rational equations do exist for the design of sludge drying beds. These are necessarily complex formulas which require the use of such empirical factors as evaporation rate, rainfall, and rate of drainage through the drying bed drainage system. Two of the most recent models are those developed by Rolan (1980) and Walski (1976). The Rolan model can be used to design and determine optimum operating parameters for drying beds. The major difference between these models and the typical explicit values is that the models account for environmental factors as well as operational factors involved in operating the sludge drying beds, which are lacking in explicit per capita values.

## DISCUSSION

The most accurate methods available for design of sludge drying beds are the use of rational equations. These equations take into account many factors not considered by per capita design values. The use of these equations in practice may be limited by their complexity and the need for empirical factors which may not make them particularly suitable for the design of small wastewater treatment plants.

Per capita design criteria are of limited value in design as they cannot account for variations in sludge quantities produced within a plant of given capacity. This is because per capita values are a function of the total wastewater flow and reflect the "typical" amounts of solids carried into or generated within the liquid treatment process train.

It must also be kept in mind that sand drying beds are primarily used to dewater digested sludge solids. Sludge volume reduction by digestion is, perhaps, the most critical step in a sludge treatment and disposal scheme and inadequacies in the digestion step can result in overloading of an otherwise adequately designed sludge drying bed.

The best approach to the design of sludge drying beds is to use solids loading criteria. These criteria best take into account the actual amount of sludge to be dewatered. However, the use of solids loading criteria are dependent upon on accurate estimations of excess activated sludge solids and the degree of sludge treatment or volume reduction achievable by intermediate operations and processes. Empirical drying bed loading rates from treatment facilities nearby to the facilitiy being designed should be used, if possible, in developing design criteria which are sensitive to local environmental factors. The use of solids loading criteria based on local empirical data will help to reduce the potential for the design of undersized sludge drying beds.

# TABLE 1

## STATE DESIGN GUIDELINES FOR SLUDGE DRYING BEDS

| Source | Open ($ft^2$/cap) | Covered ($ft^2$/cap) | Open (lb/$ft^2$/yr) | Covered (lb/$ft^2$/yr) | Other | Comments |
|---|---|---|---|---|---|---|
| Maryland | 1.75-2.5 | 1.25-1.5 | | | | $1^o$ + A.S. |
| Utah | 1.75 | | | | | 2 beds minimum |
| Iowa | 2 | | | | | 1 $ft^2$/cap if used as backup |
| Wyoming | | | | | 4 ft/yr | |
| Kansas | 1 | | | | | |
| Arizona | | | 15 | | | $1^o$ + $2^o$ digested |
| | | | 10 | | | $2^o$ digested |
| Missouri | 2 | | | | | |

## TABLE 2
## SLUDGE DRYING BED SIZING

| Source | Sludge Source | Open (ft$^2$/cap) | Covered (ft$^2$/cap) | Open (lb/ft$^2$/yr) | Covered (lb/ft$^2$/yr) | Comments |
|---|---|---|---|---|---|---|
| Vesiland (1979) | primary digested | 1 - 1.5 | 0.75 - 1 | 10 - 25 | 12 - 40 | |
| | primary plus activated dig. | 1.75 - 2.5 | 1.25 - 1.5 | | | |
| | primary plus chem. precip. digested | 2 - 2.5 | 1.25 - 1.5 | | | |
| Clark, et al. (1977) | | 1 - 2 | | 20 (Northern climates)<br>40 (Southern climates) | | Nominal 25' x 100' of 6" to 9" coarse sand or graded gravel bed. 18" of wall above surface. Pump in 8" to 10" of sludge. Pipes spaced at 20'. |
| Metcalf and Eddy (1979) | primary | 1 - 1.5 | | 24 - 40 | | Bed 20' x 20'-100'. Piping spaced 8' to 20'. 15" to 18" walls (partitions). 9" to 12" sand. 8" to 12" sludge |
| | 1° + act. dig. | 1.75 - 3 | | 12 - 20 | | |
| | 1° + chem. precip. digested | 2 - 2.5 | | 20 - 32 | | |
| Great Lakes (1971) | | 2 when bed is primary method of dewatering<br>1 when bed is back-up | | | | Gravel 12" thick extending 6" above top of drain pipes. Pipes 4" spaced less than 20'. 6"-9" of sand. Walls 15" to 18" above surface extending 6" below surface |
| Imhoff (1956) | 1° | 1.3 | | 18.25 | | Up to about 4' of sludge per year. This is 8" sludge layers with about 6 draws per year. |
| | Activated | 2.25 | | | | |
| Beardsley (1976) | | Using polymer, a bed can often be loaded with 20% to 25% more sludge | | | | |
| WPCF MOP NO. 20 (1985) | w/o Chemicals | | | 10-25 | 12-40 | |
| | w/Chemicals | | | | 40-60 | |

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