# Report for 2003GU21B: Explore the Operational Effectiveness of Saipans Existing Slow Sand Filter and Develop Recommendations to improve Operation of the Filter Plant

There are no reported publications resulting from this project.

Report Follows

# PROJECT SYNOPSIS REPORT

**Project Title:** Exploring the Operational Effectiveness of Saipan's Existing Slow Sand Filter and Develop Recommendations to improve Operation of the Filter Plant.

## Problem and Research Objectives

The Saipan slow sand filter facilities were originally constructed in 1984 and they were rehabilitated in 1992: The system includes: a) a 20 million gallon storage reservoir catching direct rainwater runoff from Saipan International Airport (Isley Field), b) a pumping station next to the rainwater catchment reservoir that delivers water to the filters through an 8 inch PVC pipe, c) two parallel slow sand filters that are constructed of concrete and each measure 100 feet by 35 feet and, d) a nearby reservoir that stores finished water from the filter.

The rainwater reservoir is a 20 MG concrete lined earthen reservoir that serves as a collection point for runoff from the airport runways. There are two vertical turbine type pumps next to the reservoir that are sized to supply the maximum slow sand filter output of 700 gpm with both pumps operating. The original design allows for the pumps to be controlled manually or automatically. Due to break down of the automatic switches, the pumps are operated manually.

The slow sand filter units consist of two 100 feet long by 35 feet wide by 12 feet deep concrete structures connected by a common center wall. Each unit was designed to process water at a maximum rate of 350 gpm. The equipment provided at the slow sand filter site includes inlet piping, filter sand and under drain system, outlet piping, and filter controls such as valves and level sensors for measuring and controlling the water level in the filters. Water enters each of the filters via an 8-inch water main from the rainwater catchments pump station. The inlet flow is controlled separately to each filter by a gate valve. Each filter's sand and under drain system includes a 4 foot depth fine sand bed that is lying on a drain system that consists of 6-inch PVC well screen laterally spaced at 4 feet off a central 8-inch diameter header. The outlet piping from each filter consists of an automatic butterfly valve for outlet flow control, a flow meter to provide the control signal to the butterfly valve, and sampling taps for water quality measurement. There is a 4-inch diameter cross connection at the discharge end of the filters tapping into the filters just above the sand layer. A level sensing probe is mounted in a standpipe that is tied to the center of this pipe. The probe senses the level in the filters and controls the pump operation at the rainwater pump station thus maintaining the water level in the filter. As mentioned earlier, the automatic control doesn't work and the pumps are manually turned off and on. There are also piezometers on the outlet face of each of the filters. The piezometers measure the water level and pressure upstream and downstream of the filter media. Presently these piezometers are not working and they need to be replaced.

According to the Commonwealth Utility Commission (CUC), the Saipan slow sand filters have not been able to deliver the design flow, which is 350 gpm since 1993. A recent flow measurement indicates that the filters are delivering 50 to 60 gpm, which is 17 % of the design flow of 350 gpm. In addition, Department of Environmental Quality (DEQ) does not have a record of data that shows how effective the filters are in removing bacteria and turbidity.

The objective of this project was to monitor the quality and the quantity of the water that is being produced by the Saipan Slow Sand Filters, and then to make recommendations on how to improve the system operation in order to increase the finished outflow from the plant.

**Methodology**

The methods that were proposed were: a) filter preparation which included draining the filters, scraping the top layer of the filter media, and replacing all the valves and flow controls, b) monitoring and testing the filter out flow for turbidity and bacteria removal, and c) evaluating the filter performance and providing recommendations of filter operation, filter scraping time, and controlling the inflow/outflow to the filters.

During the filter preparation phase, the filtration media was tested using sieve analysis to determine the size distribution of the sand. The results of the sieve analysis for both filters are shown in Table 1 and a graphical representation of the size distribution of the sieve analyses are shown in Figure 1. This analysis technique allows for determination of the $d_{10}$ and $d_{60}$ of the sand. The d represents the diameter of particles passing through a given sieve size. The $d_{10}$ (effective grain size) is determined by the sieve size that 10 percent of a sample (by weight) passes through during a sieve test. The $d_{60}$ represents the particle size that 60 percent of a sample (by weight) passes through in a sieve test. Combining these two values as a ratio of $d_{60}/d_{10}$ allows for determination of the uniformity coefficient (UC) of the material. The recommended effective grain size ($d_{10}$) for slow sand filter is 0.15 mm – 0.30 mm (0.006 in – 0.012 in) with UC value < 5 (preferably <3).

**Table 1. Sieve analysis for Saipan's Slow Sand Filters No. 1 and 2**

| Sieve Size | Opening passed through (in) | Opening passed through (mm) | Filter No. 1 % | Filter No. 2 % |
|---|---|---|---|---|
| No. 10 | 0.078 | 2 | 99.25 | 97.7 |
| No. 16 | 0.046 | 1.18 | 46.25 | 44.7 |
| No. 18 | 0.039 | 1 | 15.25 | 16.08 |
| No. 35 | 0.019 | 0.5 | 1.75 | 2.28 |
| No. 60 | 0.009 | 0.25 | 1.25 | 1.78 |
| No. 120 | 0.0045 | 0.125 | 1.1 | 1.58 |
| No. 230 | 0.0025 | 0.063 | 1.04 | 1.5 |

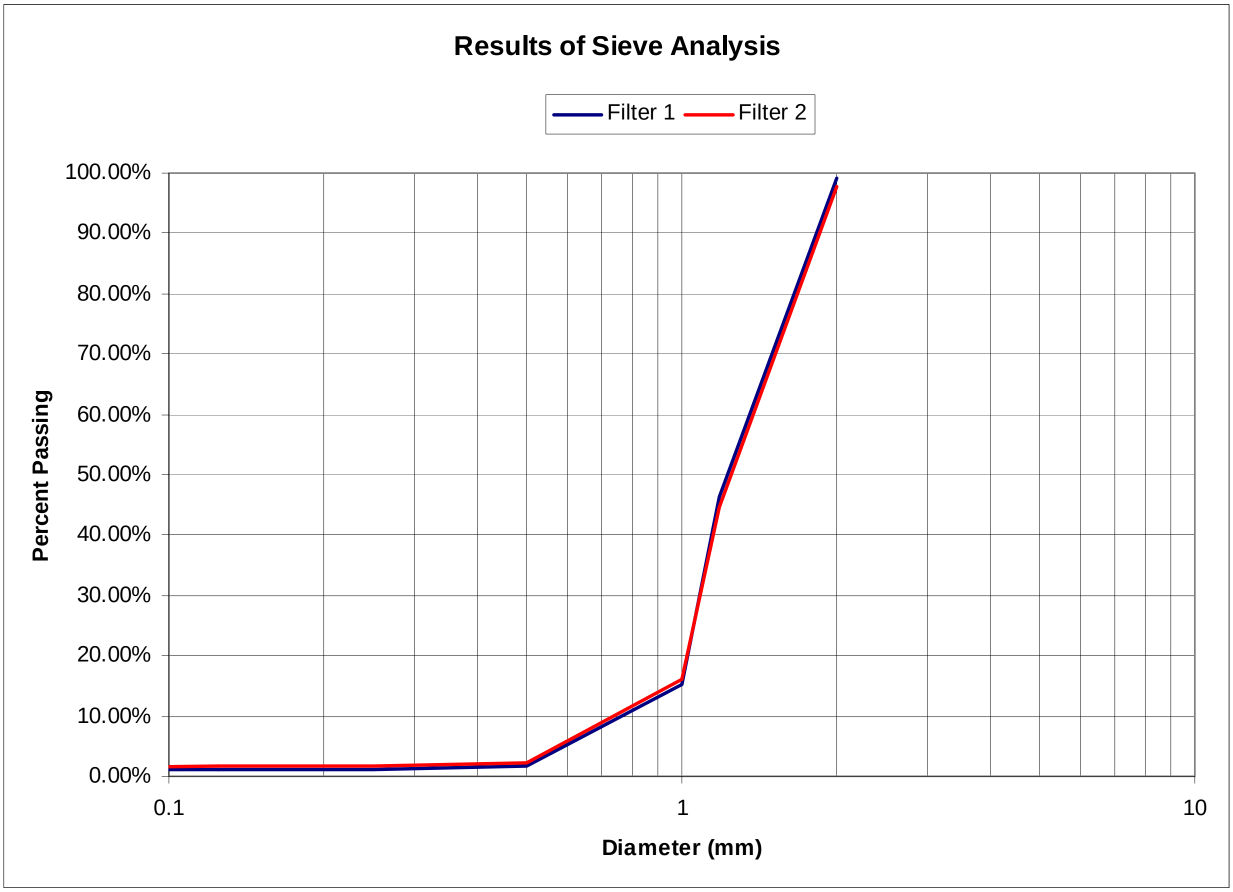


**Figure 1. Size distribution curves from sieve analysis of filter 1 and 2 of Saipan Slow Sand Filter**

## Principal Findings and Significance

The Slow Sand Filter bed media plays the main role in microbial, viral, and sediment removal. Particulate removal in slow sand filtration is considered a passive process, differing from rapid sand filtration in that chemical pre-treatment of inflow is generally not performed and back flushing (pressurized flow reversal) is not used for cleaning the filter media. In rapid sand systems, filtration requires flocculation to coagulate particles contained in the inflow, coupled with back flushing every 1-2 days to dislodge coagulated particles trapped in the media. In contrast, slow sand water purification depends upon two passive removal mechanisms: 1) biological and 2) physical-chemical; neither of which is well understood. Removals attributed to biological activity within the filter media are absent in rapid sand filters, due to the aforementioned processes that prevent establishment of biological communities within the filtration media.

The sand media for slow sand filters should follow design criteria such as the effective size of the sand $d_{10}$ should be in the range of 0.15 mm – 0.3 mm (0.006 in – 0.012 in) and the Uniformity Coefficient (UC) that is $UC = d60/d_{10}$ should be in the range of less than 5 and preferably less than 3. The UC is a reflection of the degree of variation in particles sizes. A lower UC indicates more uniformity in particle size, which generally results in a higher porosity, assuming the particles are uniform in shape. A higher UC indicates greater variation in particle sizes and usually indicates reduced porosity, as the voids created by larger particles fill with smaller sizes. These characteristics of uniformity coefficients serve as guidelines for determining porosity, however, the geometry of the sand particles has a considerable impact on the degree of sorting and hence, porosity of the media.

Table 2 shows effective size d10 and d60 and UC of the bed media of the Saipan Slow Sand Filter. The graphical representation of the size distribution of the sieve analyses for filter one and two are shown in Figure 1. The graph provides a means for obtaining the diameters of various percentages (10%, 60% etc.) of particles passing through a particular sieve. For comparison, the lower and higher limits of the size distribution for slow sand filter has been plotted in Figure 2. These limits were obtained from a slow sand filter web page. According to this figure the sand size distribution of the Saipan slow sand filter is far out of the range considered as acceptable for slow sand filters. We did a plot of a typical sand size distribution for rapid sand filter that is shown in Figure 1. The sand size distribution for rapid sand filter were also obtained from the rapid sand filter web sites.

The significant finding of this project is that: a) the sand bed media that are currently in place at the Saipan's Slow sand filter are not following the design specifications for slow sand filter bed media requirement, b) the bed media are more appropriate for rapid sand filters. Probably during the system rehabilitation in 1992, the original sand bed media was replaced by media suitable for rapid sand filters. We strongly recommended that the filter bed media be replaced with media that follows the recommended sand size distribution for slow sand filtration technology.

**Table 2. Comparison of d10, d60, and UC for Saipan's Slow Sand Filter 1 and 2**

| Filter Media | d10 (Size of percent passing – mm) | d60 (size of percent passing – mm) | Uniformity coefficient (UC) d60/d10 |
|---|---|---|---|
| Filter 1 | 0.85 | 1.52 | 1.76 |
| Filter 2 | 0.84 | 1.52 | 1.76 |

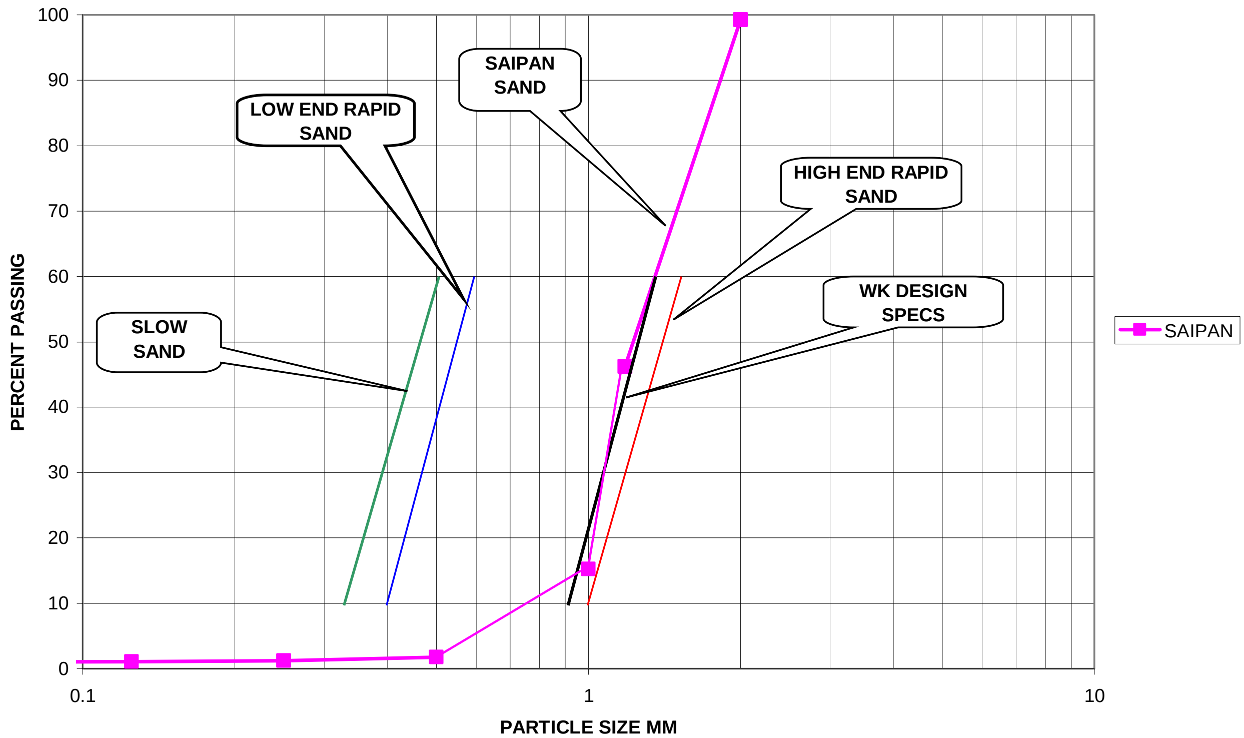


**Figure 2. Comparison of Size distribution curves from sieve analysis of filter 1 and 2 of Saipan Slow Sand Filter with Rapid Sand Filtration.**