PRIMARY EFFLUENT FILTRATION WITH A PULSED BED FILTER

A TECHNICAL NOTE

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LIST OF FIGURES AND TABLES

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ACKNOWLEDGEMENTS AND DISCLAIMER

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ERM would like to thank Gary Garzenetti (formerly of Hydro-Clear Corporation), and Neil Neymier and James Force of Hydro-Clear Corporation for their assistance in technical review of the Hydro-Clear® filter as applied to primary effluent filtration (PEF). These individuals provided product literature, case study evaluations, and technical discussions valuable to the completion of the review.

SECTION 1

I. Description of the Process and Process Options

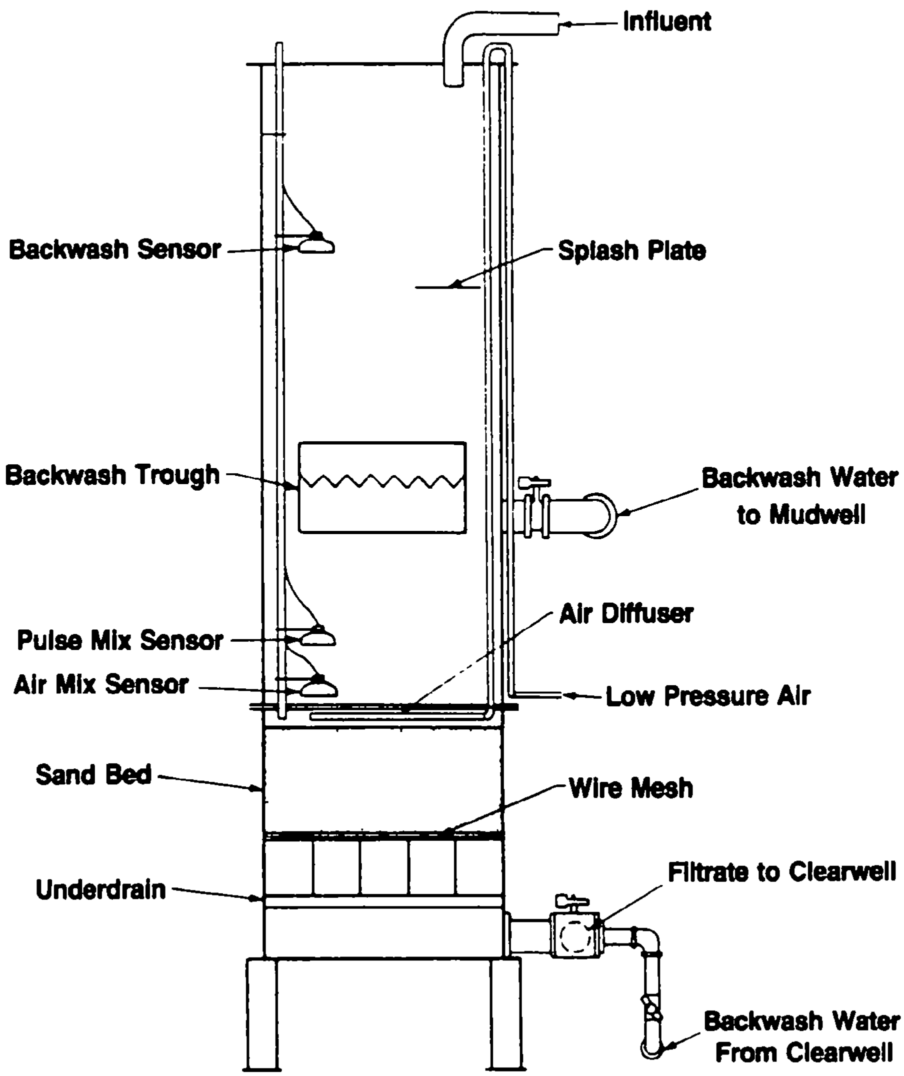
A. Process and Process Options

Primary effluent filtration (PEF) has been attempted before with various filter systems but has shown recent success only as a new application of the Hydro-Clear® Pulsed Bed Filter manufactured by Hydro-Clear Corporation. The manufacturer has extensively tested this filter for secondary and tertiary filtration and obtained a patent for both complete, prepackaged or partially assembled designs. In addition, Hydro-Clear promotes primary effluent filtration, a process which it claims cannot be efficiently accomplished by conventional deep-bed filters (Reference: "Hydro-Clear PEF: A Dramatic Breakthrough in Wastewater Treatment," Hydro-Clear Corporation). Figure 1 shows a cross-section of the Pulsed Bed Filter.

The Pulsed Bed Filter has five standard features and one optional one, important in the filtration of primary effluent (Reference: "Operation of the Hydro-Clear® Filter," Hydro-Clear Corporation). First, the filter contains uniform, fine-grained sand in order to remove solids by surface straining. Second, low-pressure Air-Mix® diffusers release fine bubbles just above the sand surface. The diffusers are designed to prolong the filter run by keeping influent solids suspended above the bed and by scouring solids from the bed surface. Third, the filter uses a Pulse-Mix® cycle consisting of air forced up through the filter at preset intervals, in order to dislodge solids clogging the surface of the bed and subsequently trap them within the bed. These three concepts are not unique to the Hydro-Clear® filter.

A fourth Hydro-Clear® filter feature is an underdrain system designed to allow proper functioning of the Pulse-Mix® cycle. Its design includes modular spaces in which atmospheric air accumulates and evenly spaced perforations to allow water and air into the sand bed during various cleaning cycles. During the pulsed air cycle, underdrain valves close to stop the drain of water. Backwash pumps then force water into the air chamber, and propel the air through the perforations and up through the sand bed. The underdrain system is also designed to provide the Hydro-Scour® backwash system, a fifth filter feature. During backwashing, pumping continues to force both the accumulated air and clean wash water up through the underdrain. This cycle is intended to wash out solids into the backwash trough with minimal bed fluidization.

Figure 1
Cross-Section Through Pulsed-Bed Pilot Filter



Not to Scale

(Adapted from "Primary Effluent Filtration: Feasibility and Applications", Hydro Clear Corporation)

Cleaning cycles are staggered among all filter cells installed. Filtration begins with the flow of wastewater over notched weirs, onto the splash plates, through the sand bed and underdrain, and to the clear well. When headloss causes the water to rise to the lowest water level indicator, the Air-Mix® diffusers are activated and operated for a preset time period as filtration continues. When headloss can no longer be lowered with the Air-Mix®, the water level builds up and touches the next highest level indicator, which is intended to initiate the Pulse-Mix® cycle without halting filtration. The Pulse-Mix® cycles on and off a preset number of times, in order to provide some headloss recovery each time. Afterwards, headloss is allowed to build up again until water touches the highest level indicator and triggers the Hydro-Scour® backwashing. The Hydro-Scour® operates for a preset length of time and is intended to completely restore the available head.

The Hydro-Clear® filter can be equipped with an optional, semi-automated Chem-Clean® system, employing alternating Hydro-Scour® and soaking cycles to wash accumulated grease and mudballs out of the bed. Cleaning chemicals, such as hyprochlorite or hydrogen peroxide, are used.

B. Existing and Proposed Installations

While over 350 Hydro-Clear® filter systems have been installed in the United States, only one retrofit filter and nine new filters have been installed for PEF in municipal systems, (Reference: Personal Communication, Hydro-Clear Corporation). Of these, six are operating, full-scale systems; three are currently operating pilot plants; and four were pilot plants that are now dismantled (Reference: "Primary Effluent Filtrations with the Hydro-Clear® Filter," Hydro-Clear Corporation). A full-scale PEF project at the Warminster, Pennsylvania Municipal Wastewater Treatment Plant was only recently completed after five years of operation. The EPA's "1985 Progress Report: Innovative and Alternative Technology Projects" indicates that the agency had funded primary effluent filtration projects at Warminster, Pennsylvania, and at three other locations. All of these projects employed Hydro-Clear® filter systems.

C. Characteristics of Primary Effluent in Municipal Systems

Primary effluent is raw wastewater that has been treated by grit removal and clarification. It often contains high concentrations of suspended and colloidal solids, which vary in organic content and range widely in particle size--anywhere from 0.08 microns to >35 microns (Reference: "Filtration of Primary Effluent," Journal of Water Pollution Control, Matsumoto et al). Studies conducted at the University of California at Davis concluded that filterable solids in primary effluent are largely organic (Reference: "The Significance of Filterable Solids in the Performance of Wastewater Treatment Processes," University of California at Davis). Table 1 shows the characteristics of a primary effluent as reported in two recent studies.

D. Manufacturer's Claims

The manufacturer cites the following main advantages of using Hydro-Clear® filters for primary effluent filtration (PEF)(Reference: Personal Communication, Hydro-Clear Corporation):

1. Removes discrete particles of less than one micron, which are found in high percentages in primary effluent. This results in decreased solids and organic loading of biological treatment systems downstream and potentially decreases the size requirements of these systems.

2. Filters primary effluent with up to six times the run time of conventional sand filters, due to the Air-Mix® and Pulse-Mix® features.

3. Requires one-sixth or less of the backwash water requirement of conventional systems due to the longer run time. This is attributed to the effects of the Hydro-Scour® and optional grease-cleaning features.

4. Efficiently filters wastewater having a wide variation in solids content due to the control of cleaning processes by water-level indicators.

In addition, the Hydro-Clear® filter reduces the relative expense of PEF by maintaining lower water levels over the bed and thus allowing the use of smaller, less expensive filter cells. Retrofits can be used to avoid some of the costs of upgrading biological systems.

II. Evaluation of Design Procedure-New Construction and Retrofits

A. Design Procedure Recommended by the Manufacturer/ Supplier

Hydro-Clear, which designs and manufactures the Hydro-Clear® filter, has provided no specific information on the actual design procedure used. However, it reports using design procedures similar to those used for conventional, uniform-grain sand filters (Reference: Personal Communication, Hydro-Clear

TABLE 1

CHARACTERISTICS OF A PRIMARY EFFLUENT

Parameter	Primary Effluent
Suspended solids, mg/l	42 to 212*
Particle size, microns	>0.1 to 35**
Total BOD_5, mg/l	55 to 191*

References:

*"Filtration of Primary Effluent," Journal, Water Pollution Control Federation, Matsumoto et al., 1982; characteristics of University of California (at Davis) Wastewater Treatment Plant primary effluent.

**"The Significance of Filterable Solids in the Performance of Wastewater Treatment Processes," Sixth Symposium on Waste Treatment, Tchobanoglous et al., 1983.

Corporation). Hydro-Clear also reports that the filter was developed over a fifteen year period based on industrial applications and their own pilot testing. Each bed-cleaning feature was added at a different time.

The manufacturer has made available the criteria it typically will use as values for filter design parameters; these criteria are presented in Table 2. Other design parameters include influent oil and grease, influent filterable solids (>0.08 micron), desired effluent quality, and expected average and peak flows. As Table 2 shows, the most significant differences between Hydro-Clear® filter and conventional deep sand filter design criteria are the smaller sand size, the lower hydraulic loading rate (HLR), and the lower rate of backwashing.

It is presumed that the following considerations are made while designing Hydro-Clear® filters for a particular wastewater application: filter cells are sized according to influent flow, Hydro-Clear design criteria, and headloss through the underdrain. Bed-cleaning features would be designed according to Table 2 criteria, although adjustments in timing and duration of cleaning cycles would be made after initial filter runs.

B. Comments on the Design Procedure

Further attempts should be made to verify the similarity between procedures used in the design of Hydro-Clear® filter and conventional sand filters. The 0.40-0.50 mm design criteria for sand size is well-supported by both earlier PEF studies and Hydro-Clear® filter/PEF system studies undertaken at the University of California at Davis.

The shallow bed depth is apparently sufficient for surface straining and for solids storage in localized area of the bed. In contrast to backwashing in deep sand filters, the Hydro-Scour uses minimal bed fluidization and would understandably require a lower design value for backwash rate and backwash water usage. Standard filter design recommendations (Metcalf and Eddy, 1979) support the manufacturers' claim that bed fluidization is not necessary for complete bed-cleaning in systems with combined air/water backwashing. Yet the duration and frequency of backwashing are more likely to be a function of influent quality and performance during initial filter runs, and less likely to conform to the specific values given as design criteria.

TABLE 2

TYPICAL DESIGN CRITERIA FOR HYDRO-CLEAR®/PEF[1] VERSUS CONVENTIONAL DEEP SAND BED/SEF[2] FILTERS

	------Typical Design Criteria------	
Design Parameters	Hydro-Clear®/PEF*	Conventional deep sand/SEF
Hydraulic loading rate, gpm per sq ft	2-4	2-8**
Sand grain size, mm	0.40-0.50	0.8-3.0**
Bed depth, inches	10	36-78**
Operating head,[3] inches	40 (typical) 60 (maximum)	variable
Volume of clearwell	2 backwash water volumes	2 backwash water volumes***
Backwash:		
Frequency, per day	6	4***
Duration, minutes	3.5-5[4]	4-6*
Rate, gpm per sq ft	12-16	44-49 for 2.0 mm sand**
Volume, per backwash gal per sq ft based on duration and rate	42-80 (8-10% of flow)	75-200***
Hydro-Scour® pulses; and duration,(seconds)	8 per backwash 20	not applicable
Auxiliary Air Scour:	(Pulse Mix®)	
Frequency	8 per filter run	1-2 times per backwash**
Duration	25-30 seconds	3 to 4 minutes**

Footnotes

1 PEF refers to primary effluent filtration
2 SEF refers to secondary effluent filtration
3 Height of water over surface of filter bed
4 Does not include time required for initial Pulse Mix

References: *Product literature and specification manual for Zimpro's Hydro-Clear® filter
**Wastewater Engineering Treatment/Disposal/Reuse, Metcalf and Eddy, 1979
***Wastewater Filtration: Design Considerations, EPA-625/4-74-007a, 1974.

III. Evaluation of System Performance

A. Availability and Suitability of Existing Operations Data

Hydro-Clear Corporation has provided hydraulic loading rates, sand sizes, and influent and effluent BOD and suspended solids data for nine out of twelve known pilot or full-scale municipal PEF systems (Reference: "Primary Effluent Filtration with the Hydro-Clear® Filter, and Attachments," Hydro-Clear Corporation). Other necessary data for evaluating filter systems, such as influent oil and grease, filter run time, frequency and duration of bed-cleaning cycles, and backwash water usage rates were available for only some case studies. Since information on actual filter designs is incomplete, the suitability of system designs cannot be fully evaluated.

B. Comments on Manufacturers' Claims

Performance data show that the Hydro-Clear® can remove between 42 and 72 percent of the suspended solids (SS) and between 22 and 66 percent of the BOD from single-stage municipal PEF systems (Reference: "Primary Effluent Filtration with the Hydro-Clear® Filter, and Attachments, Hydro-Clear Corporation). In two cases, addition of a second stage improved SS and BOD removals by about 20 and 25 percent, respectively. Backwash water usage was relatively low (7.4 percent of the influent) for one single-stage Hydro-Clear® filter/PEF system. In a single comparative study of filters operated at a hydraulic loading rate of 4 gallons per minute per square foot, a Hydro-Clear® filter removed 60 to 70 percent of influent solids compared to 30 to 57 percent removed by a multi-media filter containing sand and artificial media. (Reference: "Primary Effluent Filtration: Feasibility and Applications," University of California, Davis, 1981).

In addition, several pilot plant studies showed that the addition of a Hydro-Clear® filter for PEF could allow previously overloaded biological systems downstream to meet their discharge requirements after clarification. For instance, a pilot filter study conducted at the Clear Lake Wastewater Treatment Plant in Clear Lake, Wisconsin, showed that an almost 30 percent reduction in soluble BOD was feasible and sufficient to upgrade the capabilities of a subsequent trickling filter system to meet state regulations (Reference: "Field Evaluation of the Hydro-Clear® Pulsed Bed Filter Utilized for Primary Effluent Filtration (PEF), Hydro-Clear Corporation). A second pilot study in Avon Lake, Ohio, showed that adding a PEF filter upstream upgraded the plant's trickling filter effluent to the quality achievable with an activated sludge system without sedimentation

(Reference: "Primary Effluent Filtration: Feasibility and Applications," University of California, Davis, 1981).

The available operations information appears to substantiate Hydro-Clear's claim that the Hydro-Clear® filter can accomplish some solids and BOD removal, but is insufficient to prove all of its claims.

IV. Level of Confidence in the Concept of PEF Using a Pulsed Bed Filter

A. Influent Variability and Impact on System Performance/Suitability of System Design

In pilot studies conducted at the University of California at Davis, solids size distribution varied between 0.4 and 11 microns in the primary effluent, both before and after filtration. However, 60 to 70 percent solids removal was consistently achieved, even as influent filterable solids varied by as much as 80 percent. Therefore, it can be concluded that PEF is technologically feasible with the Hydro-Clear® filter. As with conventional filters, effluent quality decreased and backwash water usage increased as hydraulic loading rate increased.

B. Confidence in Designing a System Without the Benefit of Field Testing

Since successful solids and BOD removal have been demonstrated with a number of Hydro-Clear® filter installations, there would be a relatively low technological risk in designing a system without the benefit of additional field testing. Consequently, the Hydro-Clear® filter/PEF system would fall within Area C: Innovative Projects to Decide Fully Proven in the EPA's "Window of Risk" for characterizing the need for field testing innovative technologies. This would allow additional full-scale projects to be funded as innovative in order to provide an opportunity for more complete data collection and confirm the apparent capabilities of the Hydro-Clear® filter/PEF system.

Alternatively, more complete system monitoring programs can be developed and used to confirm the capabilities of existing, full-scale systems. Nevertheless, for any particular wastewater, a pilot plant test is needed prior to final filter design. This is especially important for applications dissimilar to previous field tests, or cases in which discharge of filtered effluent is regulated by restrictive permits.

C. **Benefits of Strengthening Certain Design Parameters Via a Field Test**

In cases where pilot (or field) testing is undertaken, such tests should indicate the optimal values for sand grain size, bed depth, hydraulic loading rate, maximum allowable headloss, and various bed-cleaning parameters, such as flow rate, frequency and duration. The expected length of filter run and the proper size of pumps, clearwells, and air diffuser systems could then be determined. Pilot tests would provide opportunities to modify the filter design prior to final construction, would help avoid necessary costs associated with undersizing or oversizing a full-scale system, and would provide operational data on which to base the design of filter systems for other similar applications.

V. **Summary of the Hydro-Clear® Filter/PEF Investigation**

The Hydro-Clear® filter employs a fine-grained, shallow sand bed and four types of bed-cleaning systems in the successful filtration of primary municipal effluents. Although nine pilot or full-scale systems have shown ability for some solids and BOD removal, the operations data are insufficient to fully evaluate either its design or degree of success. In 1986, EPA completed an extensive study of the Warminster, PA installation, which was funded as an innovative technology project. ERM would assign a relatively low technological risk to the use of the Hydro-Clear® filter for PEF. Additional monitoring could be performed on existing systems in order to obtain data for confirming the performance of the filter system. In summary, the PEF system falls within the "window of acceptable technological risk...for further innovative designation" ("Guidance on Innovative Designations", EPA, October 1984).