Grit Collection & Classification Case Studies

OWEA
2010 Specialty Biosolids Specialty Workshop

Brian F. McNamara, HRSD
Definition of Grit

Metcalf & Eddy 2nd Edition 1979

“…grit, consisting of sand, gravel, cinders, or other heavy solid materials that have subsiding velocities or specific gravities substantially greater than those of the organic putrescible solids,… Grit also includes eggshells, bone chips, seeds, coffee grounds, and large organic particles, such as food waste.”
Grit Design Parameters

Grit Removal Equipment is designed for 2.65 SG and 1 fps horizontal velocities.

Collection systems design velocities for 2 fps peak diurnal flow.

Velocity for grit re-suspension is ~ 5.0 fps

** Metcalf & Eddy 2nd Edition 1979

Notes that if the native grit specific gravity is less than 2.65, then grit removal equipment designs should be adjusted accordingly or less than 1 ft/sec horizontal velocity.
Operator View of Grit

No test to monitor grit in RWI

Measurement parameter is grit removed
Impact of Grit

• Takes up volume in down stream tanks
  • Primaries, aeration tanks, digesters, incinerators…
  • Manual labor to remove and dispose ( $$$ & Time )
• Accelerates wear on equipment
  • Primary biosolids pumps
  • Centrifuge feed pumps
  • Centrifuges
  • Collectors and screws
• Maintenance operator time and parts ( $$$ & Time )
Evaluate Entire System

Influent collection system parameters
  Gravity, force main
Pipe sizes, pump stations, vertical runs,…
Industrial loads
Diurnal flow rates, velocities
Infiltration influences
Volume of grit loads
Historical impact on treatment plant
Type of grit removal equipment
Number of grit removal units are available
Operation of grit removal equipment
How to…?

• How to sample grit?
• How to analyze grit?
• How to quantify?
• How to conduct a process review?
• How to conduct an equipment review?
• How to find historical effect of grit on treatment processes?
Obtaining a Representative Sample
Vertical Sampler
Vertical Sampler

Typical pump rate approximately 120 gpm
Vertical Sampler
Gathers a representative sample from the entire vertical water column

Slot width function of stream velocity, channel depth, pump velocity, & cross sectional area of pump suction
Sampling begins as diurnal flows raise up and continue thru the peak of the afternoon. Continuous composited for 6 hours.
Post-Sampling Activities

- Decant sample from settler
- Rinse loose floatable organics from sample
- Drain off liquid
- Volume & Weight of total sample recorded
- Wet-sieve
Wet-sieve System

Stirred! Not Shaken.
Remove Classified Grit
Laboratory Analysis & Calculations

Fixed Solids Determination

Flow weighted calculations for quantity of grit per MGD
Grit Removal Efficiency

\[
\%\text{Grit Efficiency} = \frac{\text{Grit Inf} - \text{Grit Eff}}{\text{Grit Inf}} \times 100
\]

Sample Location
Grit vs. Grit

Pilot Evaluation Comparing Two Grit Removal Technologies

Brian F. McNamara, Thomas Kochaba, Jimmie Griffiths, David Book
HRSD Army Base WWTP

- Began 1947
- 18 MGD (68 ML/d)
- Secondary WWTP
- Converted High Purity Oxygen to Surface Aeration
- Chemical P Removal
- Multiple Hearth Incinerator
Army Base WWTP Grit Channels

Plastic chain and buckets
Army Base WWTP

• Present: Grit Channels
  – Inefficient system, cannot handle slug loads

• Consequences
  – Increased wear on primary biosolids pumps
  – Grit removed from aeration tanks
  – Grit removed from holding tank
Army Base WWTP Grit Experience
2010 Plant Improvement

- 18 MGD (68 ML/d)
- Five Stage Bardenpho
  - Methanol Addition
- Distributive Control System
- Nitrification Enhancement Facility
- New Pretreatment Headworks
  - Ban Screens
  - Self Cleaning Wetwell
  - Grit Removal???
Grit Removal Technologies

- Gravity Settling
- Free Vortex (Tea Cup)
- Aerated Grit
- Forced Vortex
Grit Removal Technologies

- Gravity Settling
- Free Vortex (Tea Cup) High Energy
- Aerated Grit Poor Success
- Forced Vortex
Site Constraints
Available Technologies

- Gravity Settling
- Forced Vortex
Gravity Settling Technology
Gravity Settler Features

- Full Scale
- Two Units
- 18 MGD each (68 ML/d)
- 9 Trays
  - 12 foot dia (3.66 m)
  - 1062 ft² (98.7 m²)
- Plastic & Stainless Steel
- Two foot head loss (60 cm)
- Cut Point 100 µm @ 2.65 sg
Gravity Technology Pilot Unit

Two Trays 4 ft diameter (1.22 m)
Optimum Performance: Feed Rate 170 gpm
Cut point: 75 µm @ 2.65 sg
Forced Vortex Technology
Forced Vortex Features

- Full Scale
- Two Units
- 18 MGD each (68 ML/d)
- 22 foot diameter (6.7 m)
- Concrete & Stainless Steel
- Less than one foot head loss (30.5 cm)
- Cut point 150 µm @ 2.6 sg
Vortex Pilot Unit

4 ft dia (1.22m)
Optimum Performance: Feed Rate 180 gpm
Cut point: 106 μm @ 2.65 sg
Test Protocol

• Simultaneous Parallel testing
• Same day testing
• Use native grit from plant RWI
• Comparable flow rates
• Applicable full scale flow rates
• Same test procedures
• Same analysis
• One laboratory
Scale Up Test Protocol

Gravity Settler

Full to Pilot ratio based on SOR

<table>
<thead>
<tr>
<th>Feed Rate gpm (Lpm)</th>
<th>Cut Point</th>
<th>SOR L/m²-day</th>
<th>Comparable Plant MGD (ML/d)</th>
<th>Full Scale No. of 12 ft (3.6m) dia trays</th>
</tr>
</thead>
<tbody>
<tr>
<td>170 (643)</td>
<td>75µm</td>
<td>402,837</td>
<td>10 (40)</td>
<td>9</td>
</tr>
<tr>
<td>247 (935)</td>
<td>100µm</td>
<td>575,453</td>
<td>15 (57)</td>
<td>9</td>
</tr>
</tbody>
</table>

Forced Vortex

(Diameter Full Scale/Diameter Pilot)².² x Pilot Flow Rate = Full Scale Flow Rate

<table>
<thead>
<tr>
<th>Feed Rate gpm (Lpm)</th>
<th>Cut Point</th>
<th>Plant MGD (ML/d)</th>
<th>Diameter Full Scale</th>
</tr>
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<tbody>
<tr>
<td>180 (681)</td>
<td>106µm</td>
<td>11 (42)</td>
<td>22 ft (6.7m)</td>
</tr>
<tr>
<td>247 (935)</td>
<td>150µm</td>
<td>15 (57)</td>
<td>22 ft (6.7m)</td>
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Pilot Testing
Dual Vertical Samplers at RWI
Testing Problems

• Ultrasonic Flow Meters could not perform
  • Feed rates determined by fill test and adjusting throttle on pump motor

• Rags fouled pump suctions
  • Bar screens placed in hand

• Could not achieve pump rates of 300 gpm (1136 Lpm) or the full scale equivalent of 18 MGD (68 LPD)
  • RWI channel 22 ft deep
  • Trash pumps too small
  • Rented pumps unable to perform
10 MGD Results

Gravity Settler
39 ML/d
(10.4 MGD)
December 17, 2007

Vortex
40 ML/d
(10.5 MGD)
December 17, 2007
15 MGD Results

Gravity Settler
57 ML/d
(15.1 MGD)
December 18, 2007

Vortex
56 ML/d
(14.8 MGD)
December 18, 2007
# Pilot Unit Removal Efficiencies

<table>
<thead>
<tr>
<th>Pilot Name and Date</th>
<th>Scale Up Flow Rate MGD (ML/d)</th>
<th>Pilot Flow Rate Lpm (gpm)</th>
<th>%Removal Efficiency</th>
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<th>%Removal Efficiency</th>
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<th>%Removal Efficiency</th>
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<tbody>
<tr>
<td>Gravity</td>
<td></td>
<td></td>
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<td></td>
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</tr>
<tr>
<td>17-Dec-07</td>
<td>10.4 (39)</td>
<td>643 (170)</td>
<td>95.8</td>
<td>15.1 (57)</td>
<td>939 (248)</td>
<td>90.3</td>
<td>90.4</td>
<td>81.5</td>
<td>70.0</td>
<td>50.8</td>
<td>32.0</td>
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<tr>
<td>18-Dec-07</td>
<td>10.5 (40)</td>
<td>651 (172)</td>
<td>93.6</td>
<td>14.8 (56)</td>
<td>916 (242)</td>
<td>93.6</td>
<td>89.4</td>
<td>78.7</td>
<td>50.3</td>
<td>0.0</td>
<td>50.3</td>
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<tr>
<td>Vortex</td>
<td></td>
<td></td>
<td></td>
<td></td>
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The table above shows the pilot unit removal efficiencies for different flow rates and mesh sizes. The removal efficiencies are higher for the vortex design compared to the gravity design.
Conclusion

• Foot Print Equal
• Price Comparable
  – $1.3 Million for 2 Gravity Units
  – $1.2 Million for 2 Vortex Units
• Head loss greater for gravity unit
• Gravity settler exhibited higher removal rates at higher flows
True Grit

Full-Scale Performance Assessment of Three Common Grit Removal Technologies

Brian F. McNamara, HRSD
Jimmie Griffiths
Dave Book
## Evaluated Grit Removal Processes

<table>
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<tr>
<th>Plant</th>
<th>Equipment</th>
<th>Design Removal Parameters</th>
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</thead>
<tbody>
<tr>
<td>VIP</td>
<td>Forced Vortex 20 ft dia</td>
<td>150 (\mu m) 65% removal 26.7 MGD</td>
</tr>
<tr>
<td>CETP</td>
<td>Forced Vortex 24 ft dia</td>
<td>150 (\mu m) 95% removal 30 MGD</td>
</tr>
<tr>
<td></td>
<td></td>
<td>270 (\mu m) 95% removal 70 MGD</td>
</tr>
<tr>
<td>NTP</td>
<td>Forced Vortex 24 ft dia</td>
<td>150 (\mu m) 95% removal 50 MGD *</td>
</tr>
<tr>
<td>JRTP</td>
<td>Detritor 28 ft</td>
<td>150 (\mu m)** ?? Removal 6.5 MGD</td>
</tr>
<tr>
<td>YRTP</td>
<td>Aerated Grit 0.278 MG</td>
<td>150 (\mu m)** ?? Removal 15 MGD</td>
</tr>
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*Specs indicate both 30 MGD and 50 MGD
**Detritors & Aerated Grit derived from design literature.
**All systems reference grit at 2.65 SG

Note: All removal processes refined the grit using cyclones & classifiers.
VIP Forced Vortex 20 ft dia

Plant Design 40 MGD with Collection system composed of both gravity and force mains
VIP Forced Vortex 20 ft dia

- Plant Recycles
- Plant Drains
- Grit Influent
- Recycle
- Grit Refinement
- Final Product

- RWI
- Grit Inf = 2.3 fps
- Grit Eff = 3.5 fps
- 29 MGD
- RWI = 2.8 fps

- 54” vertical rise
- Preceded by RWI wet well
VIP  RWI  Forced Vortex 20 ft dia
VIP Forced Vortex 20 ft dia

Grit Influent
and
Grit Effluent
Plant History
VIP Forced Vortex 20 ft dia

Grit in primary biosolids

Premature wear on centrifuges

Grit volume taking up valuable incinerator space
Plant History
VIP Forced Vortex 20 ft dia

RWI flow and Incinerator feed belt totalizer during a hydraulic event.

Note: Centrifuge feed rate is constant throughout hydraulic event.
Concentration of Grit VIP Force Vortex 20 ft dia on May 20, 2007
Sunday

Grit Distribution - Concentration by Fraction

- RWI
- Grit Influent
- Grit Effluent

Ibs./MG vs. Physical Size (micron)
Average hourly flow during sampling was approximately 30 MGD

Specification requires 65% of 100 mesh (150 μm) at a maximum design flow of 26.7 MGD and 2.65 sg
System Conclusions
VIP Forced Vortex 20 ft dia

- 70% of RWI grit was over 200 microns
- > 300 micron grit shape flat, settled slowly
- Current system operation does not adequately protect downstream equipment

- Note: Plant was advised to use 2 vortexes if flows over 26 MGD
CETP Forced Vortex 24 ft dia

Plant Design 24 MGD with a collection system composed of force mains
CETP Forced Vortex 24 ft dia

- Parshall Flume
- Plant Recycles
- Grit Influent
- Grit Refinement
- Final Product

Force main collection system. Predominantly urban.

23 MGD
- RWI = 2.0 fps
- Grit Infl = 4.0 fps
- Grit Eff = 3.0 fps

Sample Location
CETP Forced Vortex 24 ft dia
RWI & Grit Influent

23 MGD   RWI = 2 fps   Grit Inf = 4 fps   Grit Eff = 3 fps
CETP Forced Vortex 24 ft dia
Grit Effluent
Prior to forced vortex units, plant used square grit chambers or Detritors.

2005 Detritors removed 24,570 ft$^3$ grit

2007 Forced vortex & hydro-cyclones removed 2,034 ft$^3$
Plant Grit Experience
CETP Forced Vortex 24 ft dia

Grit Build up in the aeration tanks

Lost Secondary Clarifier due to grit build up

Removed grit from contact tanks

Removed grit in scum concentrator
Concentration of Grit
CETP Forced Vortex 24 ft dia
RWI, Grit Influent, Grit Effluent
Thursday May 17, 2007
CETP Forced Vortex 24 ft dia Removal Efficiency

<table>
<thead>
<tr>
<th>Plant Name and Date</th>
<th>%50 Mesh (&gt;297-microns)</th>
<th>%70 Mesh (&lt;297-microns &gt;211-microns)</th>
<th>%100 Mesh (&lt;211-microns &gt;150-microns)</th>
<th>Total % Removal 150 μm &amp; up</th>
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<tbody>
<tr>
<td>Ches-Eliz Vortex</td>
<td>72.6</td>
<td>19.1</td>
<td>7.0</td>
<td>48.0</td>
</tr>
<tr>
<td>Thu, May 17, 2007</td>
<td>77.8</td>
<td>28.9</td>
<td>14.7</td>
<td>52.0</td>
</tr>
<tr>
<td>Fri, May 18, 2007</td>
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</table>

Average hourly flow during sampling was approximately 20 MGD/hour

At 30 MGD, manufacturer specifies 95% removal of 100-mesh with 2.65 sg
System Conclusions
CETP Forced Vortex 24 ft dia

- +80% of RWI grit was over 200 microns
- > 300 micron grit shape flat, settled slowly
- System did not protect downstream equipment
Nansemond Treatment Plant
24 ft Vortex

Plant Design 30 MGD
with a collection system composed of force mains
NTP Forced Vortex 24 ft dia

- **Plant Recycles**
- **Plant Drains**
- **Grit Influent**
- **Recycle**
- **Grit Refinement**
- **Grit Effluent**
- **Final Product**

22.5 MGD
RWI = 2.8 fps
Grit Inf = 1.7 fps
Grit Eff = 1.93 fps

48” vertical rise
Plant Grit Experience
NTP Forced Vortex 24 ft dia

1203 Wet Metric Tons Removed from Digester 2008
NTP Forced Vortex 24 ft dia
Removal Efficiency

<table>
<thead>
<tr>
<th>Plant Name and Date</th>
<th>#50 Mesh (&gt;297-microns)</th>
<th>#70 Mesh (&lt;297-microns &gt;211-microns)</th>
<th>#100 Mesh (&lt;211-microns &gt;150-microns)</th>
<th>Total % Removal 150 µm &amp; up</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nansemond Vortex</td>
<td>44.4</td>
<td>29.4</td>
<td>4.4</td>
<td>22.8</td>
</tr>
<tr>
<td>Tue, Mar 4, 2008</td>
<td>58.1</td>
<td>36.4</td>
<td>16.3</td>
<td>31.1</td>
</tr>
<tr>
<td>Wed, Mar 5, 2008</td>
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</tbody>
</table>

Average hourly flow during sampling was approximately 20 MGD/hour

At 50 MGD, manufacturer specifies 95% removal of 100-mesh with 2.65 sg *
System Conclusions
Nansemond 24 ft Vortex

- Over 80% of grit was less than 297 µm
- System does not adequately protect down stream equipment.
  - 1203 Metric tons removed from digester in 2008
JRTP 28 ft dia Detritor

Design 20 MGD, with a collection system composed of force mains
Detritor RWI and Grit Influent Sampling Setup

15 MGD
RWI = 2.5 fps

6 MGD
Grit Inf = 2 fps
Grit Eff = 2.5 fps
Plant Grit Experience
Detritor

No down stream grit accumulations

Digesters have not accumulated appreciable amounts of grit
Concentration of Grit Present at Plant Detritor
June 17, 2007 Sunday

Grit Distribution - Concentration by Fraction

- RWI
- Grit Influent
- Grit Effluent

Ibs/MG vs Physical Size (micron)
James River Detritor Treatment Plant Removal Efficiency

<table>
<thead>
<tr>
<th>Plant Name and Date</th>
<th>#50 Mesh (&gt;297-microns)</th>
<th>#70 Mesh (&lt;297-microns &gt;211-microns)</th>
<th>#100 Mesh (&lt;211-microns &gt;150-microns)</th>
<th>Total % Removal 150 μm &amp; up</th>
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<tbody>
<tr>
<td>James River Detritor</td>
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<td></td>
<td></td>
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</tr>
<tr>
<td>Sun, Jun 17, 2007</td>
<td>81.8</td>
<td>72.6</td>
<td>41.7</td>
<td>66.2</td>
</tr>
<tr>
<td>Mon, Jun 18, 2007</td>
<td>76.9</td>
<td>77.2</td>
<td>66.6</td>
<td>73.2</td>
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<tr>
<td>Tue, Jun 19, 2007</td>
<td>82.6</td>
<td>74.7</td>
<td>55.3</td>
<td>71.2</td>
</tr>
</tbody>
</table>

Average hourly flow during sampling was approximately 5 MGD

Optimum design flow 6.5 MGD for 100-mesh with 2.65 sg
System Conclusions

Detritor

- >40% of RWI grit was over 200 microns. Data suggest large grit deposits in collection system.
- System operated within design flows
- Plant operated with 3 detritors, providing adequate protection of downstream equipment
YRTP Aerated Grit
Tank Volume 0.278 MG

Design 15 MGD, with collection system composed of force mains.
Aerated Grit Effluent
Plant History
Aerated Grit

2006 the plant processed 12.59 MGD and collected an annual total of 807 ft$^3$ of grit

2007 Plant staff removed 14,885 ft$^3$ grit from digesters and sent to landfill
Concentration of Grit Present at the Plant
Aerated Grit
June 14, 2007 Thursday

Grit Distribution - Concentration by Fraction

<table>
<thead>
<tr>
<th>Physical Size (micron)</th>
<th>Lbs./MG</th>
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</thead>
<tbody>
<tr>
<td>50</td>
<td>2.0</td>
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<tr>
<td>75</td>
<td>2.0</td>
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<tr>
<td>100</td>
<td>2.0</td>
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<tr>
<td>150</td>
<td>2.0</td>
</tr>
<tr>
<td>200</td>
<td>2.0</td>
</tr>
<tr>
<td>300</td>
<td>2.0</td>
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<tr>
<td>820</td>
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<tr>
<td>1680</td>
<td>0.0</td>
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<tr>
<td>3180</td>
<td>0.0</td>
</tr>
<tr>
<td>6300</td>
<td>0.0</td>
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</tbody>
</table>

- RWI
- Grit Influent
- Grit Effluent
Flow Velocities

Aerated Grit

Primary Inf
Hydraulically Balanced Box

60" dia pipe
1 fps 14 MGD
0.6 fps 7 MGD

1.7 fps 14 MGD
0.7 fps 7 MGD

RWI
48" dia
System Conclusions
Aerated Grit

- Low RWI diurnal flow velocities 0.7 to 1.7 fps
- Deposition of grit in collection system
- Infiltration events achieve scouring velocities and convey slug loads into plant
- Grit system compromised during slug loads
- Primaries convey grit loads to plant digesters
Overall Conclusions

TECHNIQUE
- The grit sampling and testing methods are repeatable and meaningful
- Evaluating the overall system is necessary

EQUIPMENT (for this study)
- Detritor had the highest efficiency
- Forced vortex units had high efficiencies for large micron particles
- Forced vortex units performed better at less than design flow rates
- More testing is needed for aerated grit systems

OPERATIONAL ADVICE
- Evaluate putting more units in service to catch slug loads (first morning flows and wet weather events)

FUTURE
- More testing is desired during wet weather events
- CFD Modeling to examine how to improve performance
## True Grit Summary

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<tr>
<th>Plant Name and Date</th>
<th>%50 Mesh (&gt;297-microns)</th>
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<th>%100 Mesh (&lt;211-microns &gt;150-microns)</th>
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<td><strong>VIP Vortex</strong></td>
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<td>Sun, May 20, 2007</td>
<td>57.7</td>
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Special Thanks to my Editor

Mardane McLemore
Questions?