BAB V

DETAIL ENGINEERING DESIGN (DED) UNIT PENGOLAHAN

5.1 Saluran Pembawa

- Kriteria Perencanaan
  - Kecepatan aliran (v) = 0,3 m/detik – 0,6 m/detik

  (Sumber: Metcalf & Eddy, 2003, Wastewater Engineering Treatment & Reuse, Fourth Edition. Halaman 316)
  - Freeboard = 5% - 30%

  (Sumber: Chow, Ven Te, 1959, Open Channel Hydraulics, Mc. Graw-Hill Book Company, Inc. Halaman 159)
  - Koefisien Manning (n) untuk bahan saluran beton = 0,013

  (Sumber: Chow, Ven Te, 1959, Open Channel Hydraulics, Mc. Graw-Hill Book Company, Inc. Halaman 111)
- Desain Perencanaan
  - Menggunakan 1 aliran tertutup dengan pipa uPVC 10”
  - Debit (Q) = 1000 m^3/hari = 0,0115741 ≈ 0,012 m^3/s
  - Kecepatan aliran (v) = 0,6 m/s
  - Koef. Manning = 0,013 (untuk bahan saluran beton)
  - Free board (fb) = 25 %
  - Panjang saluran = 2,5 m
  - Percepatan gravitasi = 9,81 m/s^2
  - Massa jenis, T = 30^{O}C = 0,99568 g/cm^3

  (Sumber: Reynolds, Tom D. dan Paul A. Richards. 1996. Unit Operations and Processes in Environmental Engineering 2nd edition, hal 762 (Appendix C). Boston: PWS Publishing Company)

  - Viskositas, T = 30^{O}C = 0,8004 centipoise

(Sumber: Reynolds, Tom D. dan Paul A. Richards. 1996. Unit Operations and Processes in Environmental Engineering 2nd edition, hal 762 (Appendix C). Boston: PWS Publishing Company)

- Dimensi saluran = 2:1 W:H **(Triatmojo, Bambang. Hidrolika II. Hal.131)**

- Perhitungan
  - Luas Permukaan:

$$A = \frac{Q\ (m^3/detik)}{v\ (m/detik)}$$

(Sumber: Chow, Ven Te, 1959, Open Channel Hydraulics, Mc. Graw-Hill Book Company, Inc. Halaman 5)

$$A = \frac{0{,}012\ (m^3/detik)}{0{,}6\ (m/detik)}$$

$$A = 0{,}02\ m^2$$

  - Dimensi penampang saluran pembawa
    - Kedalaman saluran

      A = W x H → W = 2H (Bambang Triatmodjo, Hidrolika II, Hal. 131)

      $0{,}02\ m^2 = 2H^2$

      $H^2 = 0{,}01\ m^2$

      $H = \mathbf{0{,}1\ m}$

      Free board (fb) = 25% × H
      = 25% × 0,1 m
      = 0,025 m

      H total = H + free board
      = 0,1 + 0,025
      = 0,125 m

    - Lebar saluran

      W = 2H
      = 2 (0,1 m)
      = **0,2 m**

- Cek kecepatan saluran

$$A = W \times H$$
$$= 0{,}2 \times 0{,}1$$
$$= \mathbf{0{,}02\ m^2}$$
$$V_{cek} = \frac{Q}{A}$$
$$= \frac{0{,}012}{0{,}02}$$

$= \boldsymbol{0{,}6\ m/s}$ m/s (memenuhi kriteria V= 0,3-0,6)

- Jari-jari hidrolis

$$R = \frac{W \times H}{W + 2H}$$
$$= \frac{0{,}2 \times 0{,}1}{0{,}2 + 2(0{,}1)}$$
$$= 0{,}05\ \text{m} = 5\ \text{cm}$$

- Slope saluran

$$S = \left(\frac{n \times v}{R^{0{,}66}}\right)^2$$
$$= \left(\frac{0{,}012\ m^3/s \times 0{,}6\ m/s}{0{,}05^{0{,}66}}\right)^2$$

= 0,0027 m/s

- Headloss saluran

$$H_f = Q \times l$$
$$= 0{,}012 \times 2{,}5\ \text{m}$$
$$= \mathbf{0{,}03\ m}$$

- Cek bilangan Reynold

$$Nre = \frac{\rho \times R \times Vs}{\mu}$$
$$Nre = \frac{0{,}99568\ ^{gr}/_{cm^3} \times 5\ \text{cm} \times 0{,}6\ ^{m}/_{s}}{0{,}8004\ \text{centipoise}}$$

$$\text{Nre} = \frac{9{,}9568\ {}^{kg}/_{m^3} \times 0{,}05\ m \times 0{,}6\ {}^{m}/_{s}}{0{,}8004\ \times 10^{-3}\ {}^{kg.m}/_{detik}}$$

Nre = 372.43 (Nre < 2100, maka aliran laminar)

- Resume bangunan saluran pembawa
  - Menggunakan 1 saluran terbuka berbentuk rectangular
  - Panjang saluran (L) = 2,5 m
  - Lebar saluran = 0,2 m
  - Tinggi saluran total = 0,125 m
  - Kecepatan saluran = 0,6 m/s
  - Free board = 0,025 m
  - Kemiringan/slope = 0,428 m
  - Headloss saluran = 0,26 m

5.2 Bar Screen

Setelah air limbah melewati saluran pembawa, maka akan dilanjutkan ke bar screen. Dimana pada bar screen ini dapat berfungsi sebagai penyaring partikel yang berukuran besar. Hal tersebut dapat terjadi karena pada bar screen memiliki alat berongga dengan ukuran yang seragam agar dapat menahan padatan yang ada pada influent air buangan sehigga tidak mengganggu proses pengolahan selanjutnya.

- Kriteria Perencanaan
  - Lebar kisi/bar (d) = 5 – 15 mm
  - Kedalaman kisi/bar = 25 – 38 mm
  - Jarak antar kisi/bar = 25 - 50 mm
  - Kecepatan = 0,3 - 0,6 m/s
  - Headloss (Hf) = 150 mm
  - Kemiringan kisi = 45°
  - Koef saat non clogging (c) = 0,7
  - Koef saat clogging (Cc) = 0,6

(Sumber: Metcalf & Eddy, Wastewater Engineering Treatment & Reuse, Fourth Edition, page 321)

- Data Perencanaan
  - Menggunakan bar screen tipe manual (Coarse screen)
  - Debit air limbah (Q) = 1000 m^3/hari = 0,0115741 ≈ 0,012 m3/s
  - Kecepatan aliran (v) = 0,5 m/s
  - Lebar saluran (Ws)= 0,2 m
  - Tinggi saluran (Hs)= 0,125 m
  - Tinggi muka air (h) = 0,1 m
  - Lebar kisi (d) = 10 mm = 0,01 m
  - Jarak antar kisi (r)= 25 mm = 0,025 m
  - Kemiringan (t)= 45^O
  - Percepatan Gravitasi (g) = 9,87 m/s^2
  - Headloss (Hf) = 150 mm = 0,15 m

- Perhitungan
  - Jumlah batang/kisi (n)

$$Ws = n \times d + (n + 1) \times r$$

$$0,2 = n \times 0,01 + (n + 1) \times 0,025$$

$$0,2 = 0,035n + 0,025$$

$$0,175 = 0,035n$$

$$n = 5$$

  - Lebar bukaan kisi (Wc)

$$Wc = Ws - (n \times d)$$

$$= 0,2 \text{ m} - (5 \times 0,01)$$

$$= 0,195 \text{ m}$$

  - Panjang sisi miring

$$\text{Sin } \theta = \frac{\text{H bangunan}}{x}$$

$$\text{Sin } 45^o = \frac{0,125}{x}$$

$$\frac{1}{2}\sqrt{2} = \frac{0,125}{y}$$

$$x = 0,177$$

- Lebar bar screen

$$\text{Sin } \theta = \frac{\text{L bangunan}}{\text{x}}$$

$$\text{Sin } 45^{o} = \frac{\text{L bangunan}}{0{,}177}$$

$$\frac{1}{2}\sqrt{2} = \frac{\text{L bangunan}}{0{,}177}$$

$$\text{L} = 0{,}125$$

- Kecepatan melalui kisi

$$\text{Vi} = \frac{\text{Q}}{\text{Wc } \times \text{H air}}$$

$$= \frac{0{,}012}{0{,}195 \times 0{,}1}$$

$$= 0{,}6$$

- Headloss ketika non clogging

Pada saat non clogging, kecepatan melalui bar screen tersumbat, diestimasi meningkat 50%.

$$\text{Hf} = \frac{1}{\text{c}} \times \frac{\text{Vi}^2 - \text{v}^2}{2\text{g}}$$

$$= \frac{1}{0{,}7} \times \frac{0{,}615^2 - 0{,}6^2}{2(9{,}81)}$$

$$= \frac{1}{0{,}7} \times \frac{0{,}615^2 - 0{,}6^2}{2(9{,}81)}$$

$$= 0{,}001327\ m < 0{,}15 \text{ m (memenuhi kriteria)}$$

- Kecepatan ketika penggelontoran

$$\text{Vc} = \frac{Q}{50\% \times \text{Wc} \times \text{H air}}$$

$$\text{Vc} = \frac{0{,}012}{50\% \times 0{,}195 \times 0{,}1}$$

$$\text{Vc} = 1{,}23$$

- Headloss ketika clogging

$$\text{Hf} = \frac{1}{\text{c}} \times \frac{\text{Vc}^2 - \text{vi}^2}{2\text{g}}$$

$$= \frac{1}{0{,}6} \times \frac{1{,}23^2 - 0{,}615^2}{2(9{,}81)}$$

$$= 0{,}096 < 0{,}15 \text{ m (memenuhi kriteria)}$$

- Resume bangunan bar screen
    - Menggunakan bar screen tipe manual (coarse screen)
    - Jumlah kisi (n) = 5 Batang
    - Lebar bukaan (Wc) = 0,195 m
    - Kedalaman kisi = 25 mm = 0,025
    - Lebar kisi = 10 mm = 0,01 m
    - Kec. lewat kisi Bs (Vi) = 0,615
    - Hf saat non clogging = 0,001327 m
    - Hfc saat clogging = 0,096 m
    - Jarak antar kisi (r) = 25 mm = 0,025 m
    - Kemiringan (t) = 45°
    - Tinggi saluran (Hs) = 0,125 m

5.3 Bak Penampung

1. Kriteria Perencanaan
    a. Waktu detensi = < 2 jam
    (Metcalf & Eddy, 2003)
    b. Kedalaman = 1,5 – 2 m
    (Metcalf & Eddy, 2003)
    c. Freeboard = 5 – 30%
    (Chow, Ven Te, 1959)
2. Data Perencanaan
    a. Debit (Q) = 1000 m^3/hari ≈ 0,012 m^3/s
    b. Jumlah bak = 1
    c. Waktu tinggal (td) = 1 jam = 3600 detik
    d. Kedalam bak (H) = 2 m
    e. Freeboard = 30%
    f. Panjang bak (P) = 2 x Lebar bak (L)
    g. Bak penampung berbentuk persegi panjang
    h. Kecepatan aliran = 0,6 m^3/detik
3. Perhitungan
    a. Volume bak penampung

$V = Q \times td$

$V = 0{,}012\ m^3/detik \times 3600\ detik$

$V = 43.2\ m^3$

b. Dimensi bak penampung (P = 2L)

$V = P \times L \times H$

$43{,}2\ m^3 = 2L \times L \times 2\ m$

$43{,}2\ m^3 = 4(L^2)$

$L = 3{,}29\ m\ P = 6{,}58\ m$

$H_{total} = Kedalaman\ bak + freeboard$

$H_{total} = 2\ m + (30\% \times 2\ m)$

$H_{total} = 2{,}6\ m$

c. Luas bak penampung

$$\mathrm{A} = \frac{\mathrm{V}}{\mathrm{H}}$$

$$\mathrm{A} = \frac{43{,}2\ \mathrm{m}^3}{2\ \mathrm{m}}$$

$$\mathrm{A} = 21{,}6\ \mathrm{m}^2$$

d. Diameter outlet

$$A = \frac{Q}{v}$$

$$A = \frac{0{,}012\, m^3/detik}{0{,}6\, m/detik}$$

$$A = 0{,}02\ m^2$$

$$\mathrm{A} = \frac{1}{4} \times 3{,}14 \times D^2$$

$$0{,}02\ \mathrm{m}^2 = \frac{1}{4} \times 3{,}14 \times D^2$$

$$D = 0{,}159617\ \approx 0{,}160\ m$$

e. Cek waktu detensi

$$td = \frac{V}{Q}$$

$$td = \frac{P \times L \times H}{0{,}012\ m^3}$$

$$td = \frac{6{,}58\ m \times 3{,}29\ m \times 2\ m}{0{,}012\ m^3}$$

$$td = 3608\ detik = 1\ jam$$

f. Cek kecepatan (v cek) pipa outlet

v $= \frac{Q}{A}$

$= \frac{0.012\ m3/s}{\frac{1}{4}\ x\ 3{,}14\ x\ (0{,}165\ m)^2}$

= 0,56 m/s (memenuhi kriteria v = 0,3 m/s – 0,6 m/s)

g. Pompa dari Bak Penampung ke Grease Trap

1. Kriteria Perencanaan

- Berdasarkan perencanaan debit (Q) = 41,67 m^3 /jam dan head pump = 3 m yang telah diplot pada grafik performance centrifugal pump, maka diperoleh pompa sentifugal Grundfos tipe NKE 125-180/158 AA1F1S3ESBQQEGW5 dengan spesifikasi pompa sebagai berikut.
- Merk = Grundfos
- Tipe pompa = NKE 125-180/158 AA1F1S3ESBQQEGW5
- Diameter inlet = 6 inch
- Diamter outlet = 5 inch

a. $Hf_{pompa} > Hs + Hf_{total}$

b. $Hs < Hf_{pompa}$

c. Koefisien kekasaran pipa (C) = 130

d. Koefisien kekasaran aksesoris pipa (k):

- Elbow 90˚ = 0,75
- Gate Valve = 0,19
- Check valve = 2,5
- Tee = 0,50

- Increaser = 0,99

(Kawamura, S. 2000)

2. Data Perencanaan
   - Debit air limbah = 1000 m^3/hari = 0,012 m^3/detik
   - Kecepatan aliran pipa = 0,6 m/detik
   - L suction = 3 m
   - L discharge = 5 m
   - Aksesoris discharge
     - 1 Buah elbow 90°; k = 0,75
     - 1 buah check valve; k = 2,5
   - Aksesoris discharge
     - 1 buah check valve; k = 2,5
     - 2 buah elbow 90˚; k = 0,75
   - Koefisien kekasaran (C) = 130
3. Perhitungan
   a Pipa Suction
   i. Headloss mayor $= \left(\frac{Q}{0{,}2785 \times C \times D^{2{,}63}}\right)^{1{,}85} \times L$

   $= \left(\frac{0{,}012\ m^3/s}{0{,}2785 \times 130 \times (0{,}165)^{2{,}63}}\right)^{1{,}85} \times 3\ m$

   = 0.007034 m

   ii. Headloss minor
   - Check Valve $= n \times k \times \frac{v^2}{2\ x\ g}$

     $= 1 \times 2{,}5 \times \frac{(0{,}6\ m^2/s)^2}{2\ x\ (9{,}81\ m/s^2}$

     = 0,0459 m
   - Elbow $= n \times k \times \frac{v^2}{2\ x\ g}$

     $= 1 \times 0{,}75 \times \frac{(0{,}6\ m^2/s)^2}{2\ x\ (9{,}81\ m/s^2}$

     = 0,0138 m

iii. ΣHeadloss suction = 0.007034 m + 0,0138 m + 0,0459 m

= 0,06673 m

b Pipa Discharge

i. Headloss mayor $= \left(\frac{Q}{0{,}2785 \times C \times D^{2{,}63}}\right)^{1{,}85} \times L$

$= \left(\frac{0{,}012\ m^3/s}{0{,}2785 \times 130 \times (0{,}165)^{2{,}63}}\right)^{1{,}85} \times 5\ m$

= 0.011724 m

ii. Headloss minor

➢ Hf Increaser $= n \times k \times \frac{v^2}{2\ x\ g}$

$= 1 \times 0{,}9 \times \frac{(0{,}6\ m^2/s)^2}{2\ x\ (9{,}81\ m/s^2}$

= 0,01812

➢ Elbow $= n \times k \times \frac{v^2}{2\ x\ g}$

$= 2 \times 0{,}75 \times \frac{(0{,}6\ m^2/s)^2}{2\ x\ (9{,}81\ m/s^2}$

= 0,0276 m

iii. ΣHeadloss suction = 0.011724 m + 0,01812 m + 0,0276 m

= 0,057444 m

c Head statis = 2 m

d Headloss Total Discharge = Head statis + ΣHf suction + ΣHf

= 2 m + 0,06673 m +0,057444 m

= 2,1242 m < 3 m (memenuhi)

4. Resume

a. Jumlah bak penampung = 1 bak
b. Panjang bak penampung = 6,58 m
c. Lebar bak penampung = 3,29 m
d. Tinggi bak penampung = 2,5 m

5.4 Grease Trap

1. Kriteria Perencanaan
   a. Kecepatan aliran = 2-6 m/jam
   b. Waktu tinggal = 5-20 menit

   (Kementerian Pekerjaan Umum dan Perumahan Rakyat, 2017)
2. Data Perencanaan
   a. Debit (Q) = 1000 m^3/hari
      = 0,012 m^3/detik
   b. Waktu detensi (td) = 20 menit
      = 1200 detik
   c. Konsentrasi minyak dan lemak = 12 mg/l
   d. Kecepatan aliran (v) = 6 m/jam = 0,0016 m/detik
   e. Efisiensi removal minyak dan lemak = 85%
3. Perhitungan
   a. Volume

      $V = Q \times td$

      $V = 0{,}012\, m^3/detik \times 1200\ detik$

      $V = 14{,}4\, m^3$
   b. Luas area yang dibutuhkan

      $$A = \frac{Q}{v}$$

      $$A = \frac{0{,}012\ m^3/deiik}{0{,}0016\ m/detik}$$

      $A = 7{,}5\, m^2$
   c. Rasio P:L = 3:1, maka

      $A = P \times L$

      $7{,}5\, m^2 = 3L \times L$

      $L = 1{,}875\, m$

      $P = 5{,}625\, m$
   d. Panjang kompartemen 1

      $$P_1 = \frac{2}{3}\ P_{unit}$$

$$P_1 = \frac{2}{3} \times 5.625\ m$$

$$P_1 = 3{,}75\ m$$

e. Panjang kompartemen 2

$$P_2 = \frac{1}{3}\ P_{unit}$$

$$P_2 = \frac{1}{3} \times 5{,}625\ m$$

$$P_2 = 1{,}875\ m$$

f. Kedalaman tangki

$H = 2{,}5\ m\ (disamakan\ dengan\ kedalaman\ bak\ penampung)$

- Tinggi area pengendapan = 0,3 m
- Tinggi scum = 0,2 m
- Freeboard = 0,3 m

(Kementerian Pekerjaan Umum dan Perumahan Rakyat, 2017)

- Tinggi total = 2,5 m

g. Periksa kecepatan aliran

$$v_{cek} = \frac{Q}{A}$$

$$v_{cek} = \frac{0{,}012\ m^3/detik}{7{,}5\ m^2}$$

$v_{cek} = 0{,}0016\ m/detik = 5{,}76\ m/jam$ (memenuhi < 6m/jam)

h. Efluen minyak

$$efluen\ minyak = (100\% - 85\%) \times 50\ mg/l$$

$efluen\ minyak = 7{,}5\ mg/l$ (memenuhi baku mutu)

i. Dimensi pipa

$$A = \frac{Q}{v}$$

$$A = \frac{0{,}012\ m^2/detik}{0{,}6\ m/detik}$$

$$A = 0{,}02\ m^2$$

$$A = \frac{1}{4} \times 3{,}14 \times D^2$$

$$0{,}02\ m^2 = \frac{1}{4} \times 3{,}14 \times D^2$$

$$D = 0{,}159 \approx 0{,}16\ m$$

j. Jari-jari hidrolis

$$R = \frac{L \times H}{L + 2H}$$

$$R = \frac{1{,}875\ m \times 2{,}5\ m}{2{,}5\ m + 2(5{,}625\ m)}$$

$$R = 0{,}3409\ m$$

k. Slope

$$S = \left(\frac{n \times v}{R^{\frac{2}{3}}}\right)^2$$

$$S = \left(\frac{0{,}013 \times 0{,}0016\ m/detik}{(0{,}3409\ m)^{\frac{2}{3}}}\right)^2$$

$$S = 1{,}82 \times 10^{-9}\ m/m$$

l. Headloss

$$Hf = S \times P$$

$$Hf = 1{,}82 \times 10^{-9}\ m/m \times 5{,}625\ m$$

$$Hf = 1{,}02375 \times 10^{-8} m$$

4. Resume
   a. Kedalaman tangki = 2,5 m
   b. Freeboard = 0,3 m
   c. Panjang tangki = 5,625 m
   d. Lebar tangki = 1,875 m
   e. Panjang kompartemen 1 = 3,75 m
   f. Panjang kompartemen 2 = 1,875 m
   g. Tinggi masing-masing kompartemen = 1,7 m

5.5 Koagulasi

a. Kriteria Perencanaan

- Dosis alum ($Al_2(SO_4)_3$) = 75 - 250 mg/L
- Range pH alum = 4,5 – 7

  (Sumber: Eckenfelder, W., W. 2000. Industrial Water Pollution Control 3rd edition, hal 132. Singapore: McGraw Hill Companies, Inc)
- Berat jenis alum (ρ alum) = 2,67 kg/L
- Kadar air dalam alum cair = 71,2 - 74,5 %

  (Sumber: Qasim, Syed R., Motley & Zhu, G. 2000. Water Works Engineering: Planning, Design, and Operation. London: PrenticeHall)
- ρ PAC = 1,23 kg/l

  (Sumber: Reynolds, Tom D. dan Paul A. Richards. 1996. Unit Operations and Processes in Environmental Engineering 2nd edition. Boston: PWS Publishing Company)
- Massa jenis air (ρ), T (28°C) = 0,99626 g/cm3 = 996,26 kg/m3
- Viskositas Absolut (μ) T (28°C) = 0,8363 x 10-3 N.s/m2

  (Sumber: Reynolds, Tom D. dan Paul A. Richards. 1996. Unit Operations and Processes in Environmental Engineering 2nd edition, hal 762. Boston: PWS Publishing Company)
- Gradien kecepatan (G) = 700-1000/s
- Waktu detensi = 20 – 60 s

  (Sumber: Reynolds, Tom D. dan Paul A. Richards. 1996. Unit Operations and Processes in Environmental Engineering 2nd edition, hal 182. Boston: PWS Publishing Company)
- Jarak impeller dari dasar = 30 - 50% diameter impeller
- Kecepatan turbin impeller = 400-1750 rpm

(Sumber: Reynolds, Tom D. dan Paul A. Richards. 1996. Unit Operations and Processes in Environmental Engineering 2nd edition, hal 184. Boston: PWS Publishing Company)

- Lebar impeller = 1/6 – 1/10 m
- Diameter turbin impeller = 30 – 50%

  (Sumber: Reynolds, Tom D. dan Paul A. Richards. 1996. Unit Operations and Processes in Environmental Engineering 2nd edition, hal 185. Boston: PWS Publishing Company)
- Nre >10000 Turbulen

  (Sumber: Reynolds, Tom D. dan Paul A. Richards. 1996. Unit Operations and Processes in Environmental Engineering 2nd edition, hal 187. Boston: PWS Publishing Company)

b. Direncanakan

- Menggunakan koagulan PAC (1 tangki koagulan)
- Debit (Q) = 0,012 m^3/s = 1036800L/hari
- Berat jenis Alum cair (ρ PAC) = 1,23 kg/L
- Periode pelarutan Alum (td) = 1 hari
- Gradien Kecepatan (G) = 700/s
- Jenis impeller = *Propeller pitch 1, 3 blades*
- Konstanta pengaduk untuk aliran turbulen = 0,32
- Kecepatan putaran impeller (n) = 700 rpm = 11,67 rps
- Kadar alum = 60%
- Massa jenis alum = 998,2 kg/m3
- % pelarutan air = 20%

c. Perhitungan

i. Bak pembubuh koagulan

- Dosis PAC

  Reaksi kimia PAC $[Al_2(OH)_5]^+$

  Dosis PAC $= \frac{x}{berat\ molekul}\ x\ \frac{1000}{Volume\ air\ (ml)}$

$= \frac{x}{210\ g/mol}\ x\ \frac{1\ l}{12\ l/s}$

$= \frac{x\ (mg)}{2520\ g/mol.s}$

Dimana X adalah nilai dosis PAC dan ion positifnya adalah +1 sehingga ;

H^+ = - log (H^+)

1 = - log ($\frac{x\ (mg)}{2520\ g/mol.s}$)

H^+ = - log ($\frac{1\ (mg)}{2520\ g/mol.s}$)

x = 3,4 mg/l

- Kebutuhan PAC Harian

  PAC = Dosis PAC x Q

  = 3,4 mg/l x 1036800 l/hari

  = 3525120 mg/hari

  = 3,5 kg/hari

- Kebutuhan koagulan sesungguhnya

  Kebutuhan koagulan sesungguhnya $= \frac{100\%}{kadar\ PAC\%} \times kebutuhan\ PAC$

  $= \frac{100\%}{20\%} \times 3{,}5\ kg/hari$

  = 17,5 kg/hari

- Debit kebutuhan PAC

  Q_{alum} $= \frac{Massa\ PAC}{\rho\ PAC} \times td$

  $= \frac{17{,}5\ kg/hari}{1.23\ kg/l} \times 1\ hari$

  = 14,23 l/hari ≈ 0,014 m^3/hari

- Debit air pelarut

  Debit air pelarut $= \frac{100\% - \%pelarut}{\%pelarut} \times Q_{PAC}$

  $= \frac{100\% - 20\%}{20\%} \times 0{,}014\ m^3/hari$

  = 0,056 m^3/hari

- Total debit tangki pembubuh

Q_{Total} = Q alum + Q air pelarut

= 0,014 m^3/hari + 0,56 m^3/hari

= 0,07 m^3/hari = 10^{-6} m^3/s

- Volume tangki pembubuh (pembubuhan dilakukan 1 hari)

V = Q total × td

= 0,046 m^3/hari × 1 hari

= 0,46 m^3

= 460 L

Dari perhitungan volume di atas, diperoleh spesifikasi tangki pembubuhan koagulasi yang akan digunakan dalam tugas perancangan ini sebagai berikut.

- Merk = Satake
- Model Tangki = ZTF - 400
- Kapasitas Tangki = 400 l
- Kapasitas Tangki maksimum = 478 l
- Diameter Tangki = 800 mm = 0,8 m
- H air = 695 mm + 192 mm = 887 = 0,887 m
- Kedalaman Tangki = 850 mm + 192 mm = 1042 = 1,042 m
- Ketebalan Tangki = 3 mm = 0,003 m

- Daya Pengadukan

P = $G^2 \times \mu \times V$

= $(700\ /s)^2 \times 0{,}8004 \times 10^{-3}$ N.s/m^2 × 0,46 m^3

= 180,41

= 0,181 kW

Dari perhitungan power di atas, diperoleh spesifikasi pengaduk yang akan digunakan dalam tugas perancangan ini sebagai berikut.

- Merk = Satake
- Model = A720 – 0.2B
- Power = 0.2 kW
- Diameter = 0,27 m

- Jarak Impeller dengan dasar (Hi)

Hi = 50% × Di

= 50% × 0,27 m

= 0,135 m

- Cek diameter impeller

Cek D $= \frac{D\ impeler}{D\ tangki} \times 100\%$

$= \frac{0{,}27\ mm}{0{,}8\ mm} \times 100\%$

= 33,75 % (memenuhi range 30 – 50%)

- Lebar impeller

Wi $= \frac{1}{10} \times D\ tangki$

$= \frac{1}{10} \times 0{,}8\ m$

= 0,08 m

- Check Nre

Nre $= \frac{Di^2 \times n \times \rho}{\mu}$

$= \frac{(0{,}027\ m)^2 \times 11{,}67\ rps \times 995{,}68\ kg/m^3}{0{,}8004 \times 10^{-3}}$

= 10583 (>10.000 memenuhi turbulen)

- Diameter pipa outlet tangki koagulan (menuju tangki koagulasi)

A $= \frac{Q\ bak\ koagulan}{v}$

$= \frac{10^{-6}\ m^3/s}{0{,}3\ m/s}$

= $1,35 \times 10^{-6}$ m^2

D = $\sqrt{\frac{4 \times A}{\pi}}$

= $\sqrt{\frac{4 \times 1,35 \times 10^{-6}}{\pi}}$

= 0,002 m ≈ 17 mm

- Dosing pump (menuju tangki koagulasi

  Q bak pembubuh = 0,7 m^3/hari

  = 3 l/jam

Dari perhitungan volume di atas, diperoleh spesifikasi tangki koagulasi yang akan digunakan dalam tugas perancangan ini sebagai berikut.

- Merk Dosing Pump = Grundfos
- Model dosing pump = DMX 16-12
- Debit maksimal = 16 l/jam

ii. Tangki Koagulasi

- Volume air limbah

  V = Q limbah × td

  = 0,012 m^3/s × 60 s

  = 0,72 m^3

- Volume koagulan

  $V_{koagulan}$ = Q koagulan : td

  = 0,39 m^3/hari : 1 hari

  = 0,39 m^3/hari

- Volume total

  V_{total} = V limbah + V koagulan

  = 0,72 m^3 + 0,39 m^3

  = 1,11 m^3 = 1110 L

Dari perhitungan volume di atas, diperoleh spesifikasi tangki koagulasi yang akan digunakan dalam tugas perancangan ini sebagai berikut.

- Merk = Satake
- Model Tangki = ZTF - 1500

- Kapasitas Tangki = 1500 l
- Kapasitas Tangki maksimum = 1721 l
- Diameter Tangki = 1250 mm

  = 1,25 m
- H air = 1065 mm + 290 mm

  = 1,335 m
- Kedalaman Tangki = 1245 mm + 290 mm

  = 1,535 m
- Ketebalan Tangki = 4 mm

  = 0,004 m

- Daya pengadukan

  P = $G^2 \times \mu \times V$

  = $(700\ /s)^2 \times 0,8004 \times 10^{-3}$ N.s/$m^2 \times 1,11\ m^3$

  = 435,33 N.m/s

  = 0,44 kW

Dari perhitungan power di atas, diperoleh spesifikasi pengaduk yang akan digunakan dalam tugas perancangan ini sebagai berikut.

- Merk = Satake
- Model = A720 – 0.75B
- Power = 0.75 kW
- Diameter = 0,35 m

- Cek diameter impeller

  Cek D $= \frac{D\ impeler}{D\ tangki} \times 100\%$

  $= \frac{0,35\ mm}{0,8\ mm} \times 100\%$

  = 43,75 % (memenuhi range 30 – 50%)

- Lebar impeller

  Wi $= \frac{1}{10} \times D\ tangki$

$= \frac{1}{10} \times 1{,}1\ m$

= 0,11 m

- Check Nre

Nre $= \frac{Di^2 \times n \times \rho}{\mu}$

$= \frac{(0{,}35\ m)^2 \times 11{,}67\ rps \times 995{,}68\ kg/m^3}{0{,}8004 \times 10^{-3}}$

$= 1{,}78 \times 10^6$ (>10.000 memenuhi turbulen)

iii. Pipa outlet

- Debit (Q) yang keluar melewati pipa outlet

Q $= \frac{Q}{jumlah\ outlet}$

$= \frac{0{,}012\ m^3/s}{1} = 0{,}012\ m^3/s$

- Luas permukaan

A $= \frac{Q}{V}$

$= \frac{0{,}012\ m^3/s}{0{,}6\ m/s}$

= 0,02 m^2

- Diameter pipa outlet

D $= \sqrt{\frac{4A}{\pi}}$

$= \sqrt{\frac{4 \times (0{,}024\ m^2)}{\pi}}$

= 0,160 m ≈6 inch

- Cek kecepatan (v cek) pipa outlet

V_{cek} $= \frac{Q}{A}$

$= \frac{0{,}012\ m^3/s}{0{,}25 \times \pi \times (0{,}165)^2\ m^2}$

= 0,56 m/s

iv. Pompa sentrifugal ke bak flokulasi

1. Kriteria Perencanaan

Berdasarkan perencanaan debit (Q) = 41,67 m^3 /jam dan head pump = 3 m yang telah diplot pada grafik performance centrifugal pump, maka diperoleh pompa sentifugal Grundfos tipe NKE 125-180/158 AA1F1S3ESBQQEGW5 dengan spesifikasi pompa sebagai berikut.

- Merk = Grundfos
- Tipe pompa = NKE 125-180/158 AA1F1S3ESBQQEGW5
- Diameter inlet = 6 inch
- Diamter outlet = 5 inch

- Pipa Suction
  - ~ Panjang pipa suction = 1 m
  - ~ Headloss mayor (Hf mayor)

Hf mayor $= \left(\frac{Q}{0{,}2875 \times C \times D^{2{,}63}}\right)^{1{,}85} \times 1$

$= \left(\frac{0{,}012\ m^3/s}{0{,}2875 \times 130 \times (0{,}165)^{2{,}63}}\right)^{1{,}85} \times 1$

= 0.0022 m

  - ~ Headloss minor
    - ➢ Elbow $= n \times k \times \frac{v^2}{2 \times g}$

$= 2 \times 0{,}75 \times \frac{0{,}6^2}{2 \times 9{,}81}$

= 0,0275 m

  - ~ ΣTotal Headloss suction = Hf mayor + Hf elbow

= 0.0022 m + 0,0275 m

= 0,0297 m

- Pipa Discharge

~ Panjang pipa = 2 m

~ Headloss mayor (Hf mayor)

Hf mayor $= \left(\frac{Q}{0,2875 \times C \times D^{2,63}}\right)^{1,85} \times L$

$= \left(\frac{0,012\ m^3/s}{0,2875 \times 130 \times (0,165)^{2,63}}\right)^{1,85} \times 2$

= 0.0044 m

~ Headloss minor

- Elbow $= n \times k \times \frac{v^2}{2 \times g}$

  $= 2 \times 0,75 \times \frac{0,6^2}{2 \times 9,81}$

  = 0,0275 m

- Increaser $= n \times k \times \frac{v^2}{2 \times g}$

  $= 1 \times 0,25 \times \frac{0,6^2}{2 \times 9,81}$

  = 0,0046 m

~ ΣTotal Headloss discharge = Hf mayor + Hf elbow + Hf Increaser

= 0.0044 m + 0,0275 m + 0,0046 m

= 0,0365 m

- Head statis = 0 m
- Head loss total = Head statis + ΣHf suction+ ΣHf discharge

  = 0 m + 0,0297 m + 0,0365 m

  = 0.0663 m

d. Resume bangunan

Tangki pembubuh koagulan

- Q alum = 0,07 m^3/hari
- Q air pelarut = 0,56 m^3/hari

- Volume tangki pembubuh = 0,46 m^3 = 460 L
- Diameter impeller = 0,27 m
- Jarak impeller dengan dasar (Hi) = 0,135 m
- Diameter pipa outlet tangki koagulan = 0,8 m ≈ 2 inch

Tangki koagulan

- Volume tangki koagulasi = 0,72 m^3
- Diameter tangki koagulasi = 1,25 m
- H air = 1,335 m
- H total = 1,535 m
- Diameter impeller = 0,35 m
- Jarak impeller dengan dasar (Hi) = 0,175 m

5.6 Flokulasi

a. Kriteria Perencenaan

~ Waktu detensi = 15-30 menit (pengadukan lambat)

~ Gradien kecepatan = 20-75/s (pengadukan lambat)

(Sumber: Reynold, Tom D. Dan Paul A. Richards.1996. Unit Operation and Processes in Environment al Engineering 2th edition, halaman 214)

~ GT value = 50000-100000 (pengadukan lambat)

(Sumber: Reynolds, Tom D. dan Richards c. 2003. Wastewater Engineering Treatment and Reuse 4th edition, hal 199)

~ Kedalaman bak (H) = 1 – 1,25 D/W

(Reynolds, Tom D. dan Richards c. 2003. Wastewater Engineering Treatment and Reuse 4th edition, hal 184)

~ Diameter paddle (Di) = 30 – 50% D/W

~ Lebar paddle (Wi) = 1/6 – 1/10 D/W

~ Kecepatan putaran paddle (n) = 20 – 150 rpm

(Sumber: Reynolds, Tom D. dan Richards c. 2003. Wastewater Engineering Treatment and Reuse 4th edition, hal 185)

b. Data Perencanaan

~ Menggunakan bak flokulasi circular jenis flokulasi mekanik (1 bak)

~ Pengaduk menggunakan Flat Paddle, 2 Blades

~ Debit dari bak koagulasi (Q) = 0,012 m^3/s

~ Waktu detensi (td) = 15 menit = 900 s

~ Gradien kecepatan (G) = 60/s

~ Tinggi bak flokulasi = 1,25 D

~ Kecepatan pengadukan = 100 rpm = 1,3 rps

c. Perhitungan

- Volume air limbah

$V = Q_{limbah} \times td$

$= 0{,}012\ m^3/s \times 900\ s$

$= \mathbf{10{,}8\ m^3}$

- Dimensi bak (bentuk tabung)

$V = \frac{1}{4} \times \pi \times D^2 \times H$

$10{,}8\ m^3 = \frac{1}{4} \times \pi \times D^2 \times 1{,}25\ D$

$D = \mathbf{2{,}3\ m}$

- Kedalaman

$H = 1{,}25 \times D$

$= 1{,}25 \times 2{,}3\ m$

$= \mathbf{2{,}9\ m}$

- Freeboard

$Fb = 20\% \times H$

$= 20\% \times 2{,}9\ m$

$= 0{,}58\ m$

- Htotal

$H_{total} = H + Fb$

$= 2{,}9\ m + 0{,}58\ m$

$= 3{,}48 \approx \mathbf{3{,}5\ m}$

- Daya pengaduk

$P = G^2 \times \mu \times V$

= $(60/s)^2 \times 0{,}8004 \times 10^{-3}$ N.s/m^2 × 10,8 m^3

= 31,12 N.s/m

= 0,031 kW

- Diameter impeller

Di = 50% × Diameter bak

= 50% × 2,3 m

= 1,15

- Jarak impeller dengan dasar

Hi = 50% × Di

= 50% × 1,15 m

= 0,575 ≈ 0,6 m

- Lebar impeller

Wi $= \frac{1}{10} \times D\ tangki$

$= \frac{1}{10} \times 10{,}8\ m$

= 1,08 ≈ 1,1 m

- Spesfikasi agitator
  - Merk = Tacmina
  - Model = C2T-0,75
  - Power = 0,75 kW
  - Diameter = 1350 mm = 1,35 m
  - Panjang poros pengadukan = 2200 mm = 2,2 m
- Check Nre

Nre $= \frac{Di^2 \times n \times \rho}{\mu}$

$= \frac{(1{,}35\ m)^2 \times 1{,}3\ rps \times 995{,}68\ kg/m^3}{0{,}8004 \times 10^{-3}\ N.s/m^2}$

= $2{,}9 \times 10^7$ > 2000 (tidak memenuhi syarat laminer <2000)

- Check bilangan Froud

Nfr $= \frac{Di \times n^2}{g}$

$= \frac{1,35\ m \times 1,3\ rps^2}{9,81\ m/s^2}$

= 0,23 > 10^{-5} (laminer, tidak ada death zone)

- Pipa outlet
  - Debit (Q) yang keluar melewati pipa outlet

    Q $= \frac{Q}{jumlah\ outlet}$

    $= \frac{0,012\ m^3/s}{1} = 0,012\ m^3/s$
  - Luas permukaan

    A $= \frac{Q}{V}$

    $= \frac{0,012\ m^3/s}{0,6\ m/s}$

    = 0,02 m^2
  - Diameter pipa outlet

    D $= \sqrt{\frac{4A}{\pi}}$

    $= \sqrt{\frac{4 \times (0,02\ m^2)}{\pi}}$

    = 0,160 m ≈6 inch
  - Cek kecepatan (v cek) pipa outlet

    V_{cek} $= \frac{Q}{A}$

    $= \frac{0,012\ m^3/s}{0,25 \times \pi \times (0,165)^2}$

    = 0,56 m/s
- Perhitungan pompa ke bak sedimentasi

  Berdasarkan perencanaan debit (Q) = 41,67 m^3 /jam dan head pump = 3.5 m yang telah diplot pada grafik performance centrifugal pump, maka diperoleh pompa sentifugal Grundfos tipe NKE 125-180/158 AA1F1S3ESBQQEGW5 dengan spesifikasi pompa sebagai berikut.
  - Merk = Grundfos

- Tipe pompa = NKE 125-180/158 AA1F1S3ESBQQEGW5
- Diameter inlet = 6 inch
- Diamter outlet = 5 inch

▪ Headloss pipa suction

- Panjang pipa suction = 1,5 m
- Headloss mayor (Hf mayor)

Hf mayor $= \left(\frac{Q}{0{,}2785 \times C \times D^{2{,}63}}\right)^{1{,}85} \times L$

$= \left(\frac{0{,}012\ m^3/s}{0{,}2785 \times 130 \times (0{,}165)^{2{,}63}}\right)^{1{,}85} \times 1{,}5\ m$

= 0.0033 m/m

- Headloss minor (Hf minor)
  - Hf elbow $= \text{n} \times \text{k} \times \frac{v^2}{2g}$

$= 1 \times 0{,}75 \times \frac{0{,}6\ m/s}{2 \times 9{,}81\ m/s^2}$

= 0.0138 m/m

- ΣHf pipa *suction* = 0.0033 m/m + 0.0138 m/m

= 0.0171 m/m

▪ Headloss pipa discharge

- Panjang pipa discharge = 2,2 m
- Headloss mayor (Hf mayor)

Hf mayor $= \left(\frac{Q}{0{,}2785 \times C \times D^{2{,}63}}\right)^{1{,}85} \times L$

$= \left(\frac{0{,}012\ m^3/s}{0{,}2785 \times 130 \times (0{,}165)^{2{,}63}}\right)^{1{,}85} \times 2{,}2\ m$

= 0,049 m/m

- Headloss minor (Hf minor)
  - Hf elbow $= \text{n} \times \text{k} \times \frac{v^2}{2g}$

$= 1 \times 0.75 \times \frac{0{,}6\ m/s}{2 \times 9{,}81\ m/s^2}$

= 0.0138 m/m

- Hf *increaser* = n × k × $\frac{v^2}{2g}$

= 1 × 0,25 × $\frac{0,6\ m/s}{2 \times 9,81\ m/s^2}$

= 0,046 m/m

- ΣHf pipa *discharge* = 0,049 m/m + 0.0138 m/m + 0,046 m/m

= 0.0232 m/m

- Head statis = 2.6 m/m
- Headloss total sistem = 2.6 + 0.0171 + 0,0232

= 2.6403 m/m < 3 m

d. Resume

- Volume tangki flokulasi = 10.8 m^3
- Diameter tangki flokulasi = 2.4 m
- H air = 2.9 m
- H total = 3.5
- Diameter impeller = 1.35 m
- Jarak impeller dengan dasar = 0.6 m

5.7 Sedimentasi I

1. Zona pengendapan

a. Kriteria Perencanaan

- Berbentuk saluran terbuka
- Waktu tinggal (Td) = 1,5 – 2,5 jam
- Kecepatan aliran = 0,5 m/s
- Overflow rate (OFR)
  - Average = 30 – 50 m/hari
  - Peak = 70 – 130 m/hari

(Sumber: Qasim, Syed R. 1985. Wastewater Treatment Plant: Planning, Design, and Operation, hal 269. New York: CBS College Publishing)

- Weir Loading = 125 - 600 m/hari

  (Sumber: Metcalf & Eddy. 2003. Wastewater Engineering: Treatment and Reuse 4th edition, hal 398. New York: McGraw - Hill Companies, Inc)
- Specific Gravity Sludge (Sg) = 1,03
- Spesific Gravity Solids (Primary Sludge, SS) = 1,3 – 1,5

  (Sumber: Qasim, Syed R. 1985. Wastewater Treatment Plant: Planning, Design, and Operation, hal 428.. New York: CBS College Publishing)
- Dimensi
  - Panjang = 10 – 90 meter
  - Lebar = 2 – 24 meter
  - Kedalaman = 2,5 – 5 meter

  (Sumber: Metcalf & Eddy. 2003. Wastewater Engineering: Treatment and Reuse 4 th edition, hal 398. New York: McGraw-Hill Companies, Inc)
- Slope kearah Zona = 1 % - 2 %
- % removal = 50 – 80%
- Bilangan Reynold (NRe) = <2000 (aliran laminar)
- Bilangan Freud (Nfr) = > 10^{-5} (Mencegah aliran pendek)

  (Sumber: Razif, M. 1985. Pengolahan Air Minum. Surabaya: Diktat TP-FTSP-ITS)
- Syarat terjadinya pengendapan = (tp < td)
- Kecepatan horizontal (Vh) < Kecepatan pengendapan (Vs)
- Syarat terjadinya pengurasan = (Vsc > Vh)
- Percepatan gravitasi = 9,81 m/s2
- Jika temperature limbah = 30^oC
- Viskositas Kinematik = 0,8039 centistokes

TEMPERATURE (°C)	DENSITY (gms/cm^3, γ)	ABSOLUTE VISCOSITY (centipoise*, μ)	KINEMATIC VISCOSITY (centistokes*, ν)
0	0.99987	1.7921	1.7923
1	0.99993	1.7320	1.7321
2	0.99997	1.6740	1.6741
3	0.99999	1.6193	1.6193
4	1.00000	1.5676	1.5676
5	0.99999	1.5188	1.5188
6	0.99997	1.4726	1.4726
7	0.99993	1.4288	1.4288
8	0.99988	1.3872	1.3874
9	0.99981	1.3476	1.3479
10	0.99973	1.3097	1.3101
11	0.99963	1.2735	1.2740
12	0.99952	1.2390	1.2396
13	0.99940	1.2061	1.2068
14	0.99927	1.1748	1.1756
15	0.99913	1.1447	1.1457
16	0.99897	1.1156	1.1168
17	0.99880	1.0876	1.0888
18	0.99862	1.0603	1.0618
19	0.99843	1.0340	1.0356
20	0.99823	1.0087	1.0105
21	0.99802	0.9843	0.9863
22	0.99780	0.9608	0.9629
23	0.99757	0.9380	0.9403
24	0.99733	0.9161	0.9186
25	0.99707	0.8949	0.8975
26	0.99681	0.8746	0.8774
27	0.99654	0.8551	0.8581
28	0.99626	0.8363	0.8394
29	0.99597	0.8181	0.8214
30	0.99568	0.8004	0.8039
31	0.99537	0.7834	0.7870
32	0.99505	0.7670	0.7708

(Sumber: Reynolds, Tom D. and Paul A. Richards. 1996. Unit Operations and Processes in Environmental Engineering 2nd edition, hal 224. Boston: PWS Publishing Company)

- β factor kisi porositas = 0,02 – 0,12
- λ factor fraksi hidrolis = 0,03
- Tinggi air diatas pelimpah = 1 – 2 mm

(Sumber: Qasim, Syed R. 1985. Wastewater Treatment Plant: Planning, Design, and Operation, hal 278. New York: CBS College Publishing)

b. Data Perencanaan

- Menggunakan 1 bak pengendap berbentuk rectangular
- Q total = 0,012 m^3/s
- Overflow rate = 30 m/hari = 0.00035 m^3/hari
- Dengan suhu air = 30^{o}C
- Viskositas kinematis = 0,8039 × 10^{-6} m^2/dtk
- Viskositas absolut (μ) = 0,8004 × 10^{-3} m^2/dtk
- Waktu detensi (td) = 2 jam = 7200 dtk

- Kemiringan dasar bak = 2 %
- Kedalaman zona settling (H) = 3 meter
- Panjang bak = 2 × lebar bak
- % removal TSS = 70%
- Koef. Mann beton (n) = 0,015
- Spesifik gravity (ss) = 2,65
- β factor kisi porositas = 0,05
- λ factor fraksi hidrolis = 0,03
- Kemiringan plate settler = 60^o
- Tebal plate settler = 0,005 m
- Panjang area settler = 2/3 panjang zona pengendap
- Tinggi plate settler = 1,1 m
- Jarak antar plate = 0,05 m

(Visvanathan, Sedimentation Physco Chemical Processes)

c. Perhitungan

- Zona Settling
  - Debit bak settling (Q)

    Q bak $= \frac{Q\ tot}{\sum sub\ bak}$

    $= \frac{0{,}012\ m^3/s}{1}$

    $= 0{,}012\ m^3/s$

  - Volume zona Settling

    Volume $= Q \times Td$

    $= 0{,}012\ m^3/s \times 7200\ s$

    $= 86{,}4\ m^3$

  - Dimensi Sedimentasi

    $V = L \times W \times H$

    $86{,}4\ m^3 = 2W \times W \times 3$

    $= 6W^2\ m^3$

    $W^2 = 14{,}4\ m$

W = 3,79 ≈ **3,8 m**

L = 2 × 3,8 = **7,6 m**

H total = H + fb

= 3 m + (20% × 3 m)

= **3,6 m**

- Cek detensi (td)

td $= \frac{Vol}{Q} = \frac{L \times W \times H}{Q}$

$= \frac{7{,}6 \text{ m} \times 3{,}8 \text{ m} \times 3 \text{ m}}{0{,}012\ m^3/s}$

= 7220 s = 2,006 jam (memenuhi, 1,5 – 2,5 jam)

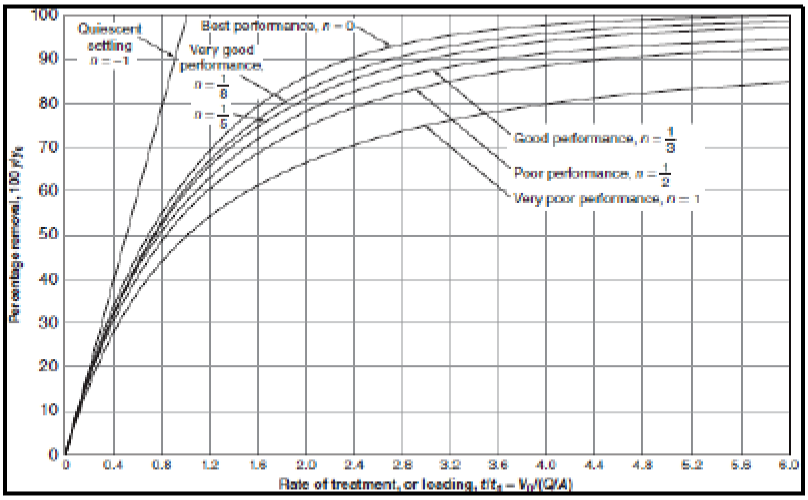
- Cek overflow rate

OFR $= \frac{Q}{A}$

$= \frac{0{,}012\ m^3/s}{7{,}6\ m \times 3{,}8\ m}$

= 0,00042 m/s = 36,3 m/hari (memenuhi 30 – 50 m/hari)

- Kecepatan pengendapan partikel (vs)



Gambar 5.1 Grafik Best Performance Penyisihan TSS

Direncanakan bak sedimentasi menghilangkan 80% kadar TSS dengan Best performace. Lalu disesuaikan dengan grafik, didapatkan nilai 2,0

Dari grafik diatas, didapat:

$\frac{vs}{OFR}$ = 2,0

$\frac{vs}{0,00042\ m/s}$ = 2,0

vs = 2,0 × 0,00048 m/s

= 0,00084 m/s

Jadi untuk mendapatkan persen removal sebesar removal sebesar 80% maka kecepatan pengendapan 0,00096 m/s

- Massa jenis partikel flok (ρ)

ρ = Sg × ρ air

= 1,03 × 995,68 kg/m^3

= 1025,55 kg/m^3

- Diameter partikel (dp)

$$dp = \sqrt{\frac{vs \times \mu \times 18}{g \times (Ss - 1)}}$$

$$= \sqrt{\frac{0,00084\ m/s \times 0,8039 \times 10^{-6}\ m^2/s \times 18}{9,81\ m^2/s \times (1,4 - 1)}}$$

= 5,56 ×10^{-5} m

- Jari-jari hidrolis (R)

$$R = \frac{\mathrm{W \times H}}{W + 2H}$$

$$= \frac{3,8 \times 3}{3,8 + 2(3)}$$

= 1,16 ≈ 1,2 m = 120 cm

- Kecepatan horizontal partikel

$$Vh = \frac{Q}{W \times H}$$

$$= \frac{0,012\ m^3/s}{3,8 \times 3}$$

= 0,0011 m/s

- Cek N_{re} Partikel

$$N_{re} = \frac{vs \times dp}{\mu}$$

$$= \frac{0,00084\ m/s \times 5,56 \times 10^{-5}\ m}{0,8039 \times 10^{-6}\ m^2/s}$$

= 0,058 (N_{Re} partikel memenuhi < 0,5)

- Cek bilangan reynold N_{Re}

Cek N_{Re} $= \frac{vh \times R}{\mu}$

$= \frac{0{,}0011\ m/s \times 1{,}2\ m}{0{,}8039 \times 10^{-6}\ m^2/s}$

= 1641,9 (Memenuhi, N_{Re} < 2000 aliran laminer)

- Cek bilangan freud (N_{Fr})

N_{Fr} $= \frac{vh^2}{g \times R}$

$= \frac{(0{,}0011\ m/s)^2}{9{,}81\ m/s^2 \times 1{,}2\ m}$

= $9{,}3 \times 10^{-5}$ (Memenuhi, NFr > 10-5)

- Cek pengurasan / kecepatan scouring (Vsc)

v_{sc} $= \sqrt{\left[\left(\frac{18 \times \beta \times g \times (Sg - 1) \times dp}{\lambda}\right)\right]}$

$= \sqrt{\left[\left(\frac{18 \times 0{,}05 \times 9{,}81 \times (1{,}03 - 1) \times 0{,}0000556}{0{,}03}\right)\right]}$

= 0,022 m/s > 0,0011 m/s

Jika Vsc (0,097 m/s) > Vh (0,0012 m/s) maka tidak terjadi pengurasan.

- Slope bak (2%) = 2% × L

= 2% × 7,6 m

= 0,152 m

- Panjang plate settler dengan kemiringan 60°

L_m $= \frac{H\ plate\ settler}{\sin 60°}$

$= \frac{1{,}1\ m}{\sin 60°}$

= **1,27 m**

- Panjang area settler (Pps)

L $= \frac{2}{3}\ L_{zona\ pengendap}$

$= \frac{2}{3} \times 7{,}6\ m$

= **5,06 m**

- Luas permukaan plate settler $= \frac{Q}{vh}\left[\frac{W}{H\cos\alpha + W\cos^2\alpha}\right]$

  $= \frac{0{,}012\ m^3/s}{0{,}0011\ m/s}\left[\frac{0{,}5}{3\cos 60° + 0{,}5\cos^2 60°}\right]$

  = 2,27 m^2

- Kecepatan aliran plate settler (vp)

  vp $= \frac{Q}{A\ settler \times \sin 60°}$

  $= \frac{0{,}012\ m^3/s}{2{,}27\ m^2 \times \sin 60°}$

  = 0,017 m/s

- Jumlah plate settler

  n $= \frac{Panjang\ area\ settler - jarak\ antar\ plate}{jarak\ antar\ settler + tebal\ settler}$

  $= \frac{5{,}06 - 0{,}05}{0{,}05 + 0{,}005}$

  = **92 buah**

- Kecepatan Vertikal

  v_v $= \frac{Q}{Jarak\ antar\ plate \times tinggi\ plate}$

  $= \frac{0{,}012\ m^3/s}{0{,}05 \times 1{,}1}$

  = 0,20 m/s

2. Zona Inlet

a. Kriteria Perencanaan

- Kecepatan aliran (v) = 0,3 – 0,6 m/s

  (Sumber: Metcalf & Eddy, Wastewater Engineering Treatment & Reuse, Fourth Edition, hlm. 316).

b. Data perencanaan

- Inlet bak pengendap = pipa outlet flokulasi
- D pipa inlet = D pipa outlet flokulasi = 8 inch
- Debit air limbah = 1000 m^3/hari = 0,012 m^3/s
- Kecepatan aliran (v) = 0,5 m/s

c. Perhitungan

- Debit (Q) yang keluar melewati pipa outlet

Q $= \frac{Q}{jumlah\ pipa\ outlet}$

$= \frac{0{,}012\ m^3/s}{1}$

= 0,012 m^3/s

- Headloss saluran pembawa (pipa)

Hf $= \left(\frac{Q}{0{,}2875 \times 130 \times D^{2{,}63}}\right)^{1{,}85} \times L$

$= \left(\frac{0{,}012\ m^3/s}{0{,}2875 \times 130 \times (0{,}165)^{2{,}63}}\right)^{1{,}85} \times 2{,}3\ m$

= 0,00509 m

- Slope pipa

S $= \frac{Hf}{L}$

$= \frac{0{,}00509\ \text{m}}{2{,}3\ m}$

= 0,0022 m/m

3. Zona sludge

a. Kriteria perencanaan

- Waktu pengurasan = 0,5 – 1 hari
- Laju aliran rata-rata = 30 – 50 m^3/m^2.hari
- Bilangan froude = 10^{-5}
- Weir loading = 125 – 500 m^3/m^2.hari
- Massa jenis limbah susu = 1030 kg/m^3*
- Massa jenis air pada limbah susu = 995.7 kg/m^3*

(*Pada suhu (T) = 30^0C)

(Walstra, P., Wouters, J.T.M., & Geurts, T.J. (2005). Dairy Science and Technology (2nd ed.). CRC Press. https://doi.org/10.1201/9781420028010)

b. Data perencanaan

Tabel 5.1 Data Influen dan Persen Removal yang Direncanakan pada Bak Sedimentasi

No.	Parameter	Influen (mg/l)	% removal

1.	TSS	530	80
2.	BOD_5	1080	80
3.	COD	2040	41,5

- Kecepatan aliran pipa penguras = 0,3 m/s
- Periode pengurasan = 1 hari
- Kadar air dalam lumpur = 90%
- Kadar SS kering = 10%
- Specific gravity = 1.635

  Babad, J., Levin, Y., & Sharon, N. (1954) *The Temperature Variation of The Specific Gravity of Recontituted Skim Milk*, Dairy Research Laboratory, Agricultural Research Station, Israel
- Berat jenis (ρs) lumpur = 1030 kg/m^3 × SS

  = 1030 kg/m^3 × 1,635

  = 1685 kg/m^3
- Berat jenis air (ρa) (T = 30) = 0,99568 g/cm3 = 9,957 kg/L
- Ruang lumpur berbentuk limas tepancung
- Panjang permukaan zona lumpur = lebar bak = 3,8 m
- Lebar permukaan zona lumpur = lebar bak = 3,8 m
- Panjang dasar zona lumpur = 3 m
- Lebar dasar zona lumpur (B') = 3 m

c. Perhitungan

- Parameter yang diendapkan di zona sludge
  1. TSS yang teremoval = %Removal × TSS influen

     = 80% × 530 mg/l

     = 424 mg/l = 0, 424 kg/m^3
  2. BOD yang teremoval = %Removal × BOD influen

     = 80% × 1080 mg/l

     = 864 mg/l = 0,864 kg/m^3
  3. COD yang teremoval = %Removal × COD influen

= 41,5% × 2040 mg/l

= 846,6 mg/l = 0,8466 kg/m^3

Total solid yang mengendap = Σremoval

= 0,424 kg/m^3 + 0,864 kg/m^3 + 0,8466 kg/m^3

= 2,14 kg/m^3

- Lumpur yang dihasilkan = Q limbah × solid yang mengedap

  = 1000 m^3/hari × 2,14 kg/m^3

  = 2140 kg/hari

- Berat air (Ww) $= \frac{kadar\ air\ dalam\ lumpur}{kadar\ padatan\ dalam\ lumpur} \times Ws$

  $= \frac{90\%}{10\%} \times 2140\ kg/hari$

  = 19260 kg/hari

- Berat jenis lumpur (ρ_s) = (Ss × 5%) + (Ww × 95%)

  = (1685 kg/m^3 × 10%) + (995,68 kg/m^3 × 90%)

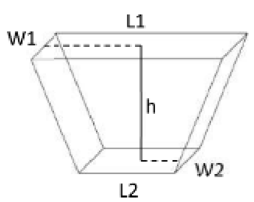
  = 896,28 kg/hari

- Volume lumpur (V) $= \frac{berat\ lumpur\ (Ws) + berat\ air\ (Ww)}{Berat\ jenis\ lumpur} \times tp$

  $= \frac{2140\ \text{kg/hari} + 19260\ \text{kg/hari}}{896{,}28\ \text{kg/m}^3} \times 1\ hari$

  = 23,88 m^3

- Dimensi zona lumpur



a. Luas permukaan atas zona lumpur

A $= L_1 \times W_1$

= 3,8 m × 3,8 m

= 14,5

b. Luas Permukaan dasar zona lumpur

A $= L_2 \times W_2$

$= 3 \text{ m} \times 3 \text{ m}$

$= 9 \text{ m}$

- Tinggi

V limas terpancung $= \frac{1}{3} \times H \times (A + \sqrt{AA'} + A')$

23,88 m^3 $= \frac{1}{3} \times H \times (14{,}5 + \sqrt{14{,}5 \times 9} + 9)$

71,64 m^3 $= 34{,}92 \text{ m}^3 \times \text{H}$

H $= 2{,}1$ m

- Debit pipa penguras sludge

Qp $= \frac{volume\ lumpur}{waktu\ pengurasan}$

$= \frac{23{,}88\ m^3}{3600\ s}$

$= 0{,}0067 \text{ m}^3/\text{s}$

- Luas pipa penguras(A)

A $= \frac{Qp}{v}$

$= \frac{0{,}0067\ m^3/s}{0{,}6\ m/s}$

$= 0{,}0112 \text{ m}^2$

- Diameter pipa penguras

D $= \sqrt{\frac{4 \times A}{\pi}}$

$= \sqrt{\frac{4 \times 0{,}0112\ m^2}{\pi}}$

$= 0{,}120$ m ≈ 5 Inches = 140 mm

- Cek kecepatan

V cek $= \frac{Qp}{A}$

$= \frac{0{,}006\ m^3/s}{0.25 \times \pi \times 0{,}14\ m \times 0{,}14\ m}$

$= 0{,}44$ m/s (memenuhi)

4. Pompa sludge ke SDB

a. Pipa suction

- Q Pengurasan lumpur = 0,0067m^3/s
- Panjang pipa suction = 12
- Headloss mayor
  - Hf mayor $= \left(\frac{Q}{0,2875 \times 130 \times D^{2,63}}\right)^{1,85} \times L$

    $= \left(\frac{0,0067}{0,2875 \times 130 \times D^{2,63}}\right)^{1,85} \times 12$

    = 0,02008 m
- Headloss minor
  - Hf elbow $= n \times k \times \frac{v^2}{2g}$

    $= 4 \times 0.75 \times \frac{0,6\ m/s}{2 \times 9,81\ m/s^2}$

    = 0.05505 m
- ΣHf pipa suction = 0,02008 m + 0.05505 m

  = 0,07512 m

b. Pipa discharge

- Panjang pipa discharge
- Headloss mayor
  - Hf mayor $= \left(\frac{Q}{0,2875 \times 130 \times D^{2,63}}\right)^{1,85} \times L$

    $= \left(\frac{0.0067}{0,2875 \times 130 \times 0.14^{2,63}}\right)^{1,85} \times 14$

    = 0.0234 m
- Headloss minor
  - Hf tee $= n \times k \times \frac{v^2}{2g}$

    $= 1 \times 1.25 \times \frac{0,6\ m/s}{2 \times 9,81\ m/s^2}$

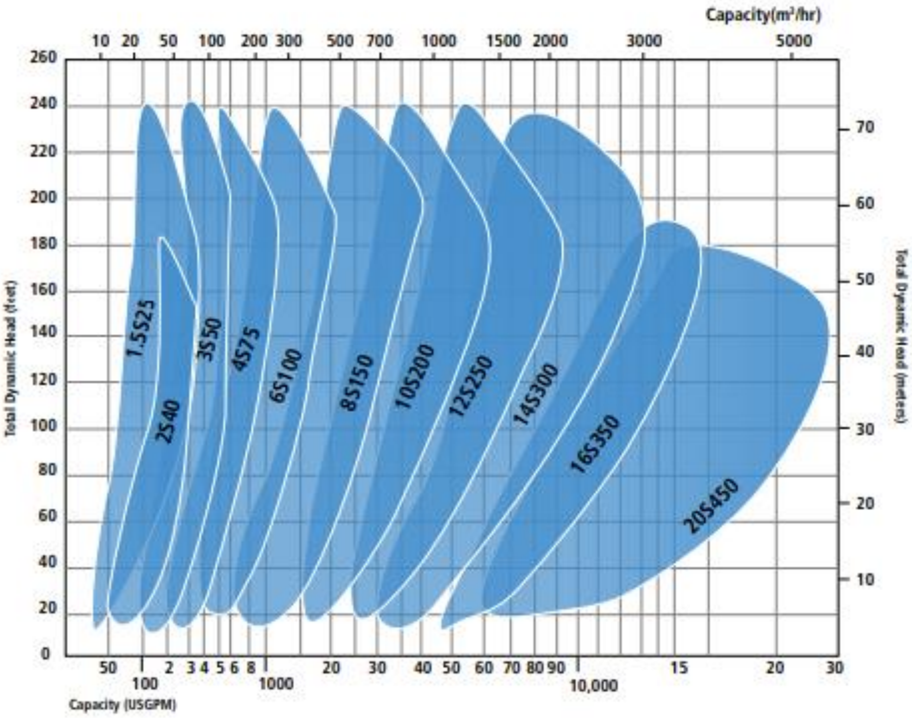
    = 0.0229 m
- ΣHf pipa discharge = 0.0234 m + 0.0229 m

  = 0,0464 m

c. Head statis = 4 m

d. Headloss total = 4 m + 0,07512 m + 0.0464

= 4.1215 m



Gambar 5.2 Grafik Pompa Lumpur
Menuju SDB

Berdasarkan grafik di atas, maka dipilih pompa dengan merek Schurco Slurry Pump S Series tipe 1,5S25 dengan spesifikasi yang tertera pada lampiran A.

5. Zona outlet

a. Kriteria perencanaan

- Kecepatan aliran pipa (v) = 0,3 – 0,6 m/s
- Weir loading rate = 125 – 500 m^3/m.hari
  (Sumber:Metcalf & Eddy, Wastewater Engineering Treatment & Reuse 4th Edition,hal 398)
- Koefisien drag (Cd) = 0,548
- Sudut V notch = 45o

(Sumber: Qasim, dkk., 2000, Water Work Engineering Planning, Design, and Operation)Bilangan froude = 10^{-5}

b. Data perencanaan

- Zona outlet bak Sedimentasi ini berupa weir bergerigi (v-notch)
- Bentuk gutter = persegi panjang
- 1 gutter = 2 pelimpah
- Lebar V notch = 0,1 m
- Jarak antar V notch = 0,05 m
- Sudut V notch = 45º
- Weir loading (m^3/m.hari) = 350 m^3/m.hari = 0,0035 m^3/m.s
- Q unit sedimentasi = 0,012 m^3/s
- Jumlah unit outlet = 1 buah
- Periode pengurasan = 1 hari
- Kadar air dalam lumpur = 90%
- Kadar SS kering = 10%
- Specific gravity = 1.635
- Direncanakan h : w pelimpah = 1 : 2
- Direncanakan lebar saluran gutter = 2 × h gutter

c. Perhitungan

➢ Gutter dan Weir

- Panjang total weir (Lw) $= \frac{Q\ bak}{Weir\ loading}$

$= \frac{0{,}012\ m^3/s}{0{,}0035\ m^3/m.s}$

= 3,43 m

- Panjang pelimpah (Lp) $= \frac{panjang\ total\ weir\ (Lw)}{Jumlah\ pelimpah\ (n)}$

$= \frac{3{,}43\ m}{2}$

= 1,73 = 1,75 m

- Debit tiap pelimpah weir

Qp $= \frac{Q\ outlet}{n}$

$= \frac{0{,}012}{2}$

= 0,006 m^3/s

- Luas saluran gutter (A) $= \frac{Q\ weir}{v}$

  $= \frac{0{,}006\ m^3/s}{0{,}5\ m/s}$

  = 0,012 m^2

- Tinggi (H) dan Lebar (W) Pelimpah (gutter)

  Direncanakan H : W = 1 : 2 maka:

  Hp $= \sqrt{2 \times A}$

  $= \sqrt{2 \times 0{,}012}$

  = 0,155 ≈ **0,16** m

  Wp $= 2 \times H$

  $= 2 \times 0{,}16\ m$

  = 0,32 m

- Ketinggian air pada pelimpah (H air)

  H air $= \left(\frac{Q\ weir}{1{,}38 \times lebar\ gutter}\right)^{2/3}$

  $= \left(\frac{0{,}006\ m^3/s}{1{,}38 \times 0{,}2\ m}\right)^{2/3}$

  = 0,07789 ≈ 0,08 m

- Tinggi gutter (h gutter)

  H gutter = h muka air + (h muka air 20%)

  = 0,08 m + (0,08 m × 20%)

  = 0,096 ≈ 0,1 m

- Jari-jari hidrolis (r gutter) $= \frac{h\ air \times lebar\ gutter}{(2 \times h\ air) + lebar\ gutter}$

  $= \frac{0{,}08\ m \times 0{,}32\ m}{(2 \times 0{,}08\ m) + 0{,}32\ m}$

  = 0,053 m

- Luas basah gutter (A gutter)

  A = lebar gutter × h air

= 0,32 m × 0,08 m

= 0,0256 ≈ 0,026 m

- Slope gutter (S) $= \left(\frac{Q\ gutter \times Q}{A\ gutter \times (R\ gutter)^{\frac{2}{3}}}\right)^2$

  $= \left(\frac{0{,}006\ m^3/s \times 0{,}012\ m^3/s}{0{,}026\ \text{m} \times (0{,}053\ m)^{2/3}}\right)^2$

  = 0,0027 m/m = 2,7 × 10^{-3} m/m

- Headloss pada gutter (Hf) = L gutter × S gutter

  = 1,73 m × 2,7 × 10^{-3} m/m

  = 4,7 × 10^{-3} m/m

➢ V notch

- Jumlah v notch (n) $= \frac{panjang\ pelimpah}{jarak\ antar\ v\ notch + lebar\ v\ notch}$

  $= \frac{1{,}73\ m}{0{,}05\ m + 0{,}1\ m}$

  = 11,53 ≈ 12 buah

- Debit mengalir tiap V notch

  Qnotch $= \frac{Q}{jumlah\ v\ notch}$

  $= \frac{0{,}012\ m^3/s}{12\ buah}$

  = 0,001 = 10^{-3} m^3/s

- Tinggi peluapan air melalui V notch (H)

  Q $= \frac{8}{15} \times (Cd) \times \sqrt{2 \times g} \times tan\frac{\theta}{2} \times H^{5/2}$

  0,001 m^3/s $= \frac{8}{15} \times (0{,}548) \times \sqrt{2 \times 9{,}81} \times tan\frac{45}{2} \times H^{5/2}$

  = 0,072 m = 7,2 cm

6. Saluran Pengumpul dan Pipa Outlet

a. Kriteria perencanaan

- Kecepatan aliran pipa (v) = 0,3 – 0,6 m/s

(Sumber: Metcalf & Eddy, Wastewater Engineering Treatment & Reuse, Fourth Edition, hal 316)

- Free board = 5% – 30% (Sumber: Chow, Ven Te. 1959. Open Channel Hydraulics, hal 159. New York, USA: Mc. Graw-Hill Book company, Inc) Koefisien drag (Cd) = 0,548

b. Data perencanaan

- Q total = 0,012 m^3/s
- Kecepatan = 0,5 m
- Lebar saluran = 6 m
- Waktu detensi = 5 menit = 300 s
- Direncanakan = H : W = 1 : 2

c. Perhitungan

- Q $= \frac{Q\ total\ bak\ sedimentasi}{jumlah\ bak}$

  $= \frac{0{,}012\ m^3/s}{1\ buah}$

  = 0,012 m^3/s

- Volume saluran

  V $= Q\ saluran\ pengumpul\ \times td$

  $= 0{,}012\ m^3/s\ \times 300\ s$

  = 3,6 m^3

- Luas saluran

  A $= \frac{Q\ saluran\ pengumpul}{v}$

  $= \frac{0{,}012\ m^3/s}{0{,}6\ m/s}$

  = 0,02 m^2

- H pelimpah

  H $= \sqrt{2 \times A}$

  $= \sqrt{2 \times 0{,}02}$

  = 0,2 m

- H total = H + (H × 20%)

  = 0,2 m + (0,2 × 20%) = 0,24 m

- Panjang pelimpah (L)

Lp $= 2 \times H\ pelimpah$

$= 2 \times 0{,}2\ m$

= 0,4 m

- Jari-jari Hidrolis

R $= \frac{luas\ keliling\ basah}{keliling\ penampang\ basah}$

$= \frac{0{,}4 \times 0{,}24}{0{,}4 + 2\ (0{,}24)}$

$= 0{,}109\ \approx 0{,}11\ m$

- Slope saluran (S)

S $= \left(\frac{v \times n}{R^{\frac{2}{3}}}\right)^2$

$= \left(\frac{0{,}6\ m/s \times 0{,}013}{(0{,}11\ m)^{2/3}}\right)^2$

= 0,0034 m/m

- Headloss Saluran Pembawa (Hf)

Hf = s × L

= 0,0034 m/m × 3,5 m

= 0,012

- Nre $= \frac{vh \times R}{\vartheta}$

$= \frac{0{,}6\ m/s \times 0{,}11\ m}{0{,}8039 \times 10^{-6}\ m^2/s}$

= 82150,86 > 10000 (memnuhi turbulen)

- Luas penampang pipa outlet

A $= \frac{Q\ saluran\ pipa\ outlet}{v}$

$= \frac{0{,}012\ m^3/s}{0{,}6\ m/s}$

= 0,02

- Diameter pipa penguras

D $= \sqrt{\frac{4 \times A}{\pi}}$

$= \sqrt{\frac{4 \times 0{,}02}{\pi}}$

= 0,159 ≈ pipa 6 inch

- Cek kecepatan

V cek $= \frac{Q}{A}$

$= \frac{0{,}012\ m^3/s}{0.25 \times \pi \times 0{,}165\ \ m \times 0{,}165\ m}$

= 0,58 m/s (memenuhi)

- Resume bangunan
  - Panjang saluran pengumpul (L) = 0.4 m
  - Lebar saluran pengumpul (W) = 3.8 m
  - Tinggi saluran pengumpul = 0.2 m
  - Freeboard (Fb) = 20%
  - Tinggi total saluran pengumpul (H_{tot}) = 0.24
  - Diameter pipa outlet saluran (D) = 6 inch

5.8 Activated Sludge

a. Kriteria Perencenaan

- Menggunakan bak activated sludge
- Umur lumpur (θc) = 4 – 10 hari
- Rasio F/M = 0,25 – 0,5 kg BOD5/kg MLVSS.d
- Ketinggian bak aerasi (H) = 3 – 5,6 m

  (Sumber: Metcalf & Eddy, Waste Water Engineering Treatment & Reuse, 4th Edition, hal 687)
- Waktu detensi (td) = 6 – 8 jam

  (Sumber: Marcos von Sperling, Activated Sludge and Aerobic Biofilm Reactors, Biological Wastewater Treatment Series, Volume Five, hal 6)
- Rasio VSS/SS = 0,70 – 0,85

(Sumber: Marcos von Sperling, Activated Sludge and Aerobic Biofilm Reactors, Biological Wastewater Treatment Series, Volume Five, hal 21)

- Particulate BOD = 0,45 – 0,65 mg.BOD5/mgTSS

  (Sumber: Marcos von Sperling, Activated Sludge and Aerobic Biofilm Reactors, Biological Wastewater Treatment Series, Volume Five, hal 29)

- Koefisien temperatur aktif (θ) = 1,04 (T = 20 – 30^{o}C)

  (Sumber: Metcalf & Eddy, Waste Water Engineering Treatment & Reuse, 4thEdition, hal 681)

- Yield Coefficient (Y) = 0,5 – 0,7 g VSS/g BOD5 removed
- Endogenous Respiration Coefficient (Kd) = 0,06 – 0,10 g VSS/g VSS.d

  (Sumber: Marcos von Sperling, Activated Sludge and Aerobic Biofilm Reactors, Biological Wastewater Treatment Series, Volume Five, hal 20)

- Standard oxygenation efficiency = 1,8 kg O2/kW.jam

  (Sumber: Marcos Von Sperling, Activated Sludge and Aerobic Biofilm Reactor, hal 66)

- Ketinggian bak aerasi (H) = 4.5 – 7.5 m

  (Sumber: Metcalf & Eddy, Waste Water Engineering Treatment & Reuse, 4th Edition, hal 817)

- Rasio Resirkulasi (R) = 0,6 – 1
- Ketinggian bak aerasi (H) = 4.5 – 7.5 m

  (Sumber: MetcalF & EDDY, WASTE WATER ENGINEERING TREATMENT & REUSE, 4TH EDITION, HAL 817)

- Rasio Resirkulasi (R) = 0,6 – 1
- MLVSS (Xv) = 1500 – 3500 mg/L
- MLSS (X) = 2000 – 4000 mg/L
- Biodegradable Fraction of VSS (fb) = 0,55 – 0,77

(Sumber: Marcos von Sperling, Activated Sludge and Aerobic Biofilm Reactors, Biological Wastewater Treatment Series, Volume Five, hal 69)

- Effluent soluble BOD = 5 – 20 mg/L

  (*Sumber: Marcos Von Sperling, Activated Sludge and Aerobic Biofilm Reactor, hal 69*)

- Kebutuhan O_2 = 0,8 – 0,94 kg O_2/kg BOD removed

  (Sumber: Marcos Von Sperling, Activated Sludge and Aerobic Biofilm Reactor, hal 205)

b. Desain Perencanaan

- Direncanakan menggunakan 1 buah bak activated sludge jenis conventional
- Debit (Q) = 1000 m^3/hari = 0,012 m^3/s
- Umur lumpur (θc) = 7 hari
- Rasio VSS/SS = 0,8
- MLVSS (Xv atau Xa) = 2800 mg/L
- MLSS (X) = 3000 mg/L
- *Yield Coefficient* (Y) = 0,6 gVSS/g BOD5 removed
- *Endogenous Respiration Coefficient* (Kd) = 0,075 g VSS/g VSS.d
- Suhu = 30°
- Rasio Resirkulasi (R) = 0,9
- Standard oxygenation efficiency = 1,8 kg O_2/kW.jam
- Biodegradable fraction of VSS (fb) = 0,75
- (VSS/SS) rasio = 0,8
- Effluent Soluble BOD = 5 mg/l

Tabel 5.2 Tabel Perencanaan Penyisihan Parameter Penyisihan

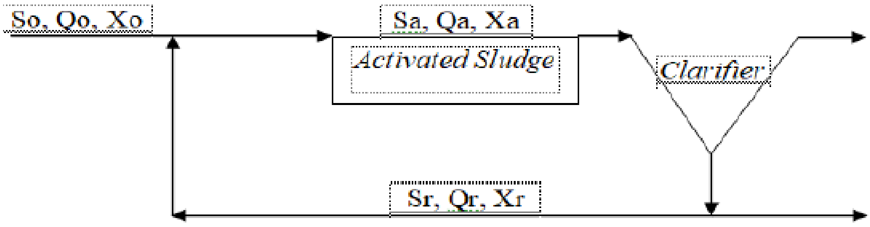
Parameter	Influen (mg/l)	Removal (%)	Effluen (mg/l)	Baku mutu (mg/l)
BOD	216	80	43,2	40
COD	1193,4	92	95,472	100
Nitrogen	25	80	5	10

- Koefisien temperature aktif = 1,04 ($T = 30^0C$)
- Massa jenis lumpur (γ) = Sg × p

  = 1,3 x 1030 kg/m^3

  = 1339 kg/m^3
- Kedalaman bioreaktor (H) = 3 m
- Kebutuhan O_2 = 0,9 kg O_2/kg BOD removed
- O_2/Sr = 0,83 kg O2/kg BOD5
- Konsentrasi Lumpur (C) = 3 %

c. Perhitungan



Qo = Debit influent

Qa = Debit di dalam reaktor

Qr = Debit resirkulasi

So = Konsentrasi organik (BOD influent)

Sa = Konsentrasi organik (BOD di dalam reaktor)

Sr = Konsentrasi organik (BOD effluent)

Xa = Konsentrasi mikroorganisme dalam reaktor (MLVSS)

Xr = Konsentrasi mikroorganisme pada lumpur yang disirkulasikan (MLSS)

1. Removal polutan
   - BOD Effluen = BOD influent – (%removal × BOD influent)

     = 216 – (80% × 216)

     = 43,2 mg/l
   - COD Effluen = COD influent – (%removal × COD influent)

     = 1193,4 – (92% × 1193,4)

= 95,472 mg/l

- Nitrogen Effluen = N influen – (%removal × N influen)

= 25 – (80% × 25)

= 8 mg/l

2. Partikulat BOD Efluen

V = (VSS/SS) × fb

= 0,8 × 0,7 = 0,56 mg BOD/mg SS

Maka, untuk effluent BOD sebesar 43,2 mg/L

BOD partikulat = 0,56 × 43,2 mg/l = 24,2 mg/l

3. Total BOD Effluen

T BOD = BOD terlarut + partikulat BOD

= 5 mg/l + 24,2 mg/l

= 29,2 mg/l

4. BOD yang teremoval = BOD influen (Co) × % removal

= 216 × 80%

= 172,8 mg/l

5. BOD yang disirkulasi (Cr) = BOD influen (Co) – BOD yang teremoval

= 216 mg/l – 172,8 mg/l

= 43,2 mg/l

6. Debit resirkulasi

Qr = Qo × R

= 1000 m^3/hari × 0,9

= 900 m^3/hari = 900000 L/hari ≈ 10,42 L/detik

7. Debit total bak activated sludge

Qtot = Qo + Qr

= 1000 m^3/hari + 900 m^3/hari

= 1900 m^3/hari ≈ 0,022 m^3/detik ≈ 1900800 L/hari ≈ 22 L/detik

8. Volume bak activated sludge

$$V = \frac{Y \times \theta c \times Qtot \times (So - Sa)}{Xa \times (1 + Kd \times fb \times \theta c)}$$

$$= \frac{0{,}7\ g\ VSS/g\ BOD5 \times 7\ hari \times 1900\ m^3/_{hari} \times (216\ mg/l - 5\ mg/l)}{2500\ mg/l \times (1 + 0{,}075\ hari \times 0{,}7 \times 7\ hari)}$$

$= 513{,}03\ m^3$

9. Dimensi bak activated sludge (P = 2L, H = 3,25)

$V = P \times L \times H$

$513{,}03\ m^3 = 2L \times L \times 3{,}25\ m$

$513{,}03\ m^2 = 6{,}5\ L^2$

$$L = \sqrt{\frac{513{,}03\ m^2}{6{,}5}}$$

$L = 8{,}88 \approx 8{,}9\ m$

$P = 2L$

$= 2 \times 8{,}9\ m = 17{,}8\ m$

H bangunan = H air + H fb

= 3,25 + (3,25 × 20%)

= 3,9 m

$V_{max} = P \times L \times H$

$= 17{,}8\ m \times 8{,}9\ m \times 3{,}9\ m$

$= 617{,}84\ m^3$

10. Konsentrasi resirkulasi lumpur

$$Xr = \frac{X(Qa + Qr)}{Qr}$$

$$= \frac{3000\ mg/l\ (0{,}012\ m^3/s + 0{,}01\ m^3/s)}{0{,}01\ m^3/s}$$

= 6600 mg/l

11. Produksi lumpur setiap hari

$$\text{Koefisien} = \frac{y}{1 + (kd \times \theta c)}$$

$$\text{y observed} = \frac{0{,}7\ g\ VSS/g\ BOD5}{1 + (0{,}075\ hari \times 7\ hari)}$$

(y obs) = 0,46

12. Penyisihan beban BOD

Sr = Qo × (So – S)

= (0,012 m^3/s × 1000 l/m^3 × 86400 s/d) × (216 mg/l – 5 mg/l)

= 218764800 mg/d = 218,76 kg/hari

Sr = BOD effluen – BODss

= 43,2 mg/l – (24,2 mg/l + 5 mg/l)

= 14 mg/l

13. Konsntrasi BOD dalam bak activated sludge (Sa)

$$Sa = \frac{(So \times Qo) + (Sr \times Qr)}{(Qo + Qr)}$$

$$= \frac{(216\ mg/l \times 12\ l/detik) + (14\ mg/l \times 10{,}42\ l/detik)}{(12\ l/detik + 10{,}42\ l/detik)} = 122{,}11\ mg/L$$

14. Produksi lumpur (Px MLVSS)

Px MLVSS = y obs × Sr

= 0,46 × 218,76 kg/hari

= 100,63 kg.VSS/hari

15. Produksi lumpur (Px MLSS)

$$\text{Px MLSS} = \frac{\text{Px MLVSS}}{\text{VSS/SS}}$$

$$= \frac{100{,}63\ \text{kg/hari}}{0{,}8}$$

= 125,8 kg/hari

16. Debit lumput yang dibuang

Jika dibuang melalui bak pengendap

$$Qex = \frac{V}{\theta c}$$

$$= \frac{513{,}03\ m^3}{7\ hari}$$

= 73,29 m^3/hari

Jika dibuang melalui resirkulasi

$$Qex = \frac{V \times X}{\theta c \times Xr}$$

$$= \frac{513{,}03\ \text{m}^3 \times 3000\ mg/l}{7\ hari \times 6600\ mg/l}$$

= 33,31 m^3/hari

17. F/M ratio

$$F/M = \frac{Qin \times So}{vol \times Xv}$$

$$= \frac{1900\ m^3/hari \times 0{,}216\ kg/m^3}{513{,}03\ m^3 \times 2{,}8\ kg/m^3}$$

$= 0{,}286\ m^3/hari$ (memenuhi, kriteria 0.25 – 0,5)

18. Konsntrasi BOD dalam bak activated sludge (Sa)

$$Sa = \frac{(So \times Qo) + (Sr \times Qr)}{(Qo + Qr)}$$

$$= \frac{(324\ mg/l \times 12\ l/detik) + (22\ mg/l \times 9{,}2\ l/detik)}{(12\ l/detik + 9{,}2\ l/detik)} = 192{,}94\ mg/L$$

19. Volumetric loading (VL)

$$VL = \frac{Sa \times Qtot}{V}$$

$$= \frac{122{,}11\ mg/l \times 1900800\ L/hari}{513{,}03\ m^3} = 452453{,}23\ \text{mg.BOD/m}^3\text{.hari}$$

≈ 0,45 kg.BOD/m^3.hari (memenuhi kriteria 0,2 – 3 kg.BOD/m^3.hari)

20. Volume lumpur

$$V1 = \frac{Px\ MLVSS}{\gamma \times C} \times \theta c$$

$$= \frac{100{,}63\ kg/hari}{1339\ kg/m^3 \times 0{,}03} \times 7\ \text{hari}$$

= 17,54 m^3

21. Dimensi lumpur

V1 = P × L × H

17,54 m^3 = 17,8 m × 8,9 m × H

H = 0,11 m

22. Kebutuhan oksigen

$$\text{Kebutuhan } O_2 = \frac{1{,}46 \times Qin \times (Co - Cr)}{10^3}$$

$$= \frac{1{,}46 \times 1900\ {m^3}/{hari} \times (216\ mg/l - 43{,}2\ mg/l)}{10^3}$$

= 479,35 kg/hari

= 19,97 ≈ 20 kg/jam

23. Kebutuhan power aerator

Standard Efisiensi oksigen = 1,8 kg O_2/kW.jam

P $= \frac{Kebutuhan\ oksigen}{Standard\ Oxygenation\ Efficiency}$

$= \frac{20\ kg/jam}{1{,}8\ kg/kW.jam}$

= 11.1 kW

24. Tekanan pada aerator $= \rho \times g \times h$

= 995,7 kg/m^3 × 9,81 m/s^2 × 3,9 m

= 38094,5 N/m

= 3883,24 mmAq

Dari perhitungan diatas, diperoleh spesifikasi blower yang akan digunakan dalam tugas perancangan ini, yaitu sebagai berikut:

- Merk = Tsurumi Pump
- Model blower = 80TRN43.7
- Power = 3,7 kW
- Diameter = 50 mm
- Kecepatan = 55 m^3/h
- Jumlah = 4

25. Pipa outlet menuju clarifier

Direncanakan:

- v = 0,5 m/s
- Q_{out} = Q_{in}

  = 0,02 m^3/s

- Luas penampang pipa

  A $= \frac{Q}{v}$

  $= \frac{0{,}02\ m^3/s}{0{,}6\ m/s} = 0{,}036$

- Diameter pipa outlet

  D $= \sqrt{\frac{4A}{\pi}}$

$= \sqrt{\frac{4(0,036)}{\pi}} = 0,214$

Berdasarkan pipa yang ada dipasaran, didapatkan diameter sebesar 218 mm atau 8 inch.

- Cek kecepatan aliran (v cek)

v cek $= \frac{Q}{A}$

$= \frac{0,022}{0,25 \times \pi \times 0,216^2} = 0,6\ m/s$

26. Perhitungan pompa

Berdasarkan perencanaan debit (Q) = 41,67 m^3 /jam dan head pump = 6.5 m yang telah diplot pada grafik performance centrifugal pump, maka diperoleh pompa sentifugal Grundfos tipe NKE 125-180/176 AA1F1S3ESBQQEJWA dengan spesifikasi pompa sebagai berikut.

- Merk = Grundfos
- Tipe pompa = NKE 125-180/176 AA1F1S3ESBQQEJWA
- Diameter inlet = 6 inch
- Diamter outlet = 5 inch

▪ Headloss pipa suction

- Panjang pipa suction = 4 m
- Headloss mayor (Hf mayor)

Hf mayor $= \left(\frac{Q}{0,2785 \times C \times D^{2,63}}\right)^{1,85} \times L$

$= \left(\frac{0,022\ m^3/s}{0,2785 \times 130 \times (0,216)^{2,63}}\right)^{1,85} \times 4\ m$

= 0.0073 m/m

- Headloss minor (Hf minor)
  - Hf elbow = n × k × $\frac{v^2}{2g}$

$= 1 \times 0,75 \times \frac{0,6\ m/s}{2 \times 9,81\ m/s^2}$

= 0.0138 m/m

- ΣHf pipa *suction* = 0.0073 m/m + 0.0138 m/m

= 0.0211 m/m

- Headloss pipa discharge
  - Panjang pipa discharge = 17,2 m
  - Headloss mayor (Hf mayor)

Hf mayor $= \left(\frac{Q}{0,2785 \times C \times D^{2,63}}\right)^{1,85} \times L$

$= \left(\frac{0,012\ m^3/s}{0,2785 \times 130 \times (0,216)^{2,63}}\right)^{1,85} \times$ $17,2\ m$

= 0,0315 m/m

- Headloss minor (Hf minor)
  - Hf elbow $= n \times k \times \frac{v^2}{2g}$

$= 3 \times 0.75 \times \frac{0,6\ m/s}{2 \times 9,81\ m/s^2}$

= 0.0413 m/m

  - Hf *increaser* $= n \times k \times \frac{v^2}{2g}$

$= 1 \times 0,25 \times \frac{0,6\ m/s}{2 \times 9,81\ m/s^2}$

= 0,046 m/m

- ΣHf pipa *discharge* = 0.0315 m/m + 0,00413 m/m + 0,046 m/m

= 0.0773 m/m

- Head statis = 5.6 m/m
- Headloss total sistem = 5.6 + 0.211 + 0,0773

= 5.7 m/m < 6.5 m/m

27. Resume bangunan
  - Lebar bak activated sludge = 8,9 m
  - Panjang bak acticvated sludge = 17,8 m
  - Tinggi total (H_{total}) = 3,6 m

- Diameter pipa inlet = 6 inch
- Diameter pipa outlet = 8 inch

5.9 Clarifier

a. Kriteria Perencanaan

- Bentuk bak pengendap = Circular
- Kedalaman (H) = 3 – 4,9 m
- Diameter = 3 – 60 m
- Bottom slope = 1/16 – 1/6 mm/mm
- Flight speed = 0,02 – 0,05 m/menit
- Waktu detensi (td) = 1,5 – 2,5 jam
- Over flow rate

  Average = 30 – 50 m^3/m^2.hari

  Peak = 80 – 120 m^3/m^2.hari
- Weir loading = 125 – 500 m /m2.hari

  (Sumber: Metcalf & Eddy, Wastewater Engineering Treatment & Reuse, Fourth Edition, hal 398)
- Diameter inlet well = 15% – 20% diameter bak
- Ketinggian inlet well = 0,5 – 0,7 m
- Kecepatan inlet well = 0,3 – 0,75 m/s

  (Sumber: Metcalf & Eddy, Wastewater Engineering Treatment & Reuse, Fourth Edition, hal 401)
- Konsentrasi solid = 4% - 12%

  (Sumber: Metcalf & Eddy, Wastewater Engineering Treatment & Reuse, Fourth Edition, hal 411)
- % Removal TSS = 60% - 80%

  (Sumber: Huisman, hal 12)
- Specific gravity sludge (Sg) = 1,005
- Specific gravity solid (Ss) = 1,25

  (Sumber: Metcalf & Eddy, Wastewater Engineering Treatment & Reuse, Fourth Edition, hal 1456)
- Massa jenis air (ρ), T (30°C) = 0,99568 g/cm3 = 9,957

kg/L

- Viskositas kinematic (v) = $0{,}8039 \times 10^{-6}$ m^2/s
- Viskositas dinamik (μ) = $0{,}8004 \times 10^{-3}$ N s/m2

(Sumber: Reynolds, Tom D. dan Paul A. Richards. 1996. Unit Operations and Processes in Environmental Engineering 2nd edition, hal 762)

- Bilangan Reynold (NRe) untuk Vs = < 1 (laminer)

(Sumber: Reynolds, Tom D. dan Paul A. Richards. 1996. Unit Operations and Processes in Environmental Engineering 2nd edition, hal 224)

- Bilangan Reynold (NRe) untuk Vh = < 2000 (aliran laminer)
- Bilangan Froude (Nfr) = > 105

(Sumber: SNI 6774:2008 Tata Cara Perencanaan Unit Paket Instalasi Pengolahan Air, hal 6)

b. Perencanaan

- **Zona *Settling***
  - Menggunakan 1 bak *secondary clarifier* berbentuk *circular*
  - Debit (Q) = 1000 m^3/hari = 0,012 m^3/detik
  - Waktu detensi = 2 jam = 7200 detik
  - Kedalaman bak = 3,5 m
  - Massa jenis air (ρ), T (30°C) = 0,99568 g/cm^3 = 9,957 kg/L = 996 kg/m^3
  - Viskositas kinematik (v) = 0,8039 x 10^{-6} m^2/s
  - Viskositas dinamik (μ) = 0,8004 x 10^{-3} N s/m2
  - Koef. manning = 0,013
  - Over flow rate = 40 m3/m^2.hari
  - Diameter inlet well (D’) = 20% diameter bak
  - Ketinggian inlet well = 0,7 m
  - Kons. MLSS = 3000 mg/L
  - Kons MLVSS = 2000 mg/L

- MLVSS (P_{xv}) = 413,32 kg VSS/hari
- Qr = 800 m^3/hari → dari activated sludge
- % Removal TSS = 70%
- Waktu pengurasan = 3 hari
- Menggunakan V notch dengan kemiringan 45°
- Jarak antar V notch = 50 cm
- Percepatan gravitasi = 9,81 m/s^2
- Massa jenis sludge = Sg x ρ
  = 1,005 x 996 kg/m^3 = 1000,98 kg/m^3
  = 1030 kg/m^3

(Walstra, P., Wouters, J.T.M., & Geurts, T.J. (2005). Dairy Science and Technology (2nd ed.). CRC Press. https://doi.org/10.1201/9781420028010)

c. Perhitungan

- Zona Settling

1. Q_{in} pada clarifier

   Q_{in} = $Q_o + Q_r$
   = 1000 m^3/hari + 900 m^3/hari
   = 1900 m^3/hari ≈ 0,022 m^3/detik ≈ 1900800 L/hari ≈ 22 L/detik

2. Luas surface area (A)

   $$A = \frac{Qin}{OFR}$$
   $$= \frac{1900\ m^3/hari}{40\ m^3/m^2.hari}$$
   = 47,5 m^2

3. Diameter

   $$D = \sqrt{\frac{4 \times A}{\pi}}$$
   $$= \sqrt{\frac{4 \times 47{,}5\ \mathrm{m}^2}{\pi}}$$

$= 7{,}78 \approx 7{,}8$ m (memenuhi syarat 3 – 60 m)

r $= \frac{D}{2}$

$= \frac{7{,}8\ m}{2} = 3{,}9\ m$

4. Luas Surface Area Baru

A $= \frac{1}{4} \times \pi \times D^2$

$= \frac{1}{4} \times \pi \times (7{,}8\ m)^2$

$= 47{,}78\ m^2$

5. Cek *Overflow Rate*

OFR $= \frac{Qin}{A}$

$= \frac{1900\ m^3/hari}{47{,}78\ m^2}$

$= 39{,}76\ m^3/m^2.hari$ (memenuhi syarat 30 – 50 m^3/m^2.hari)

6. Volume bak

V $= A \times H$

$= 47{,}78\ m^2 \times 3{,}5\ m^3 = 167{,}23$

7. Cek waktu detensi

t_d $= \frac{V}{Qin}$

. $= \frac{167{,}23\ m^3}{0{,}022\ m^3/s}$

= 7601 s = 2.11 jam

Kecepatan pengendapan partikel (vs)

v_s $= \frac{H}{td}$

$= \frac{3{,}5\ m}{7601\ s} = 0{,}00046$ m/s

8. Diameter partikel (Dp)

Dp $= \sqrt{\frac{v_S 18\ v}{g\ (S_s - 1)}}$

$= \sqrt{\frac{0{,}00046\ m/s \times 18 \times 0{,}8039 \times 10^{-6}\ m^2/s}{9{,}81\ m/s^2\ (1{,}25 - 1)}} = 5{,}21 \times 10^{-5}$ m

9. Cek bilangan N_{RE} Vs

N_{RE} $= \frac{\rho_s \times D_p \times v_s}{\mu}$

$= \frac{1030\ kg/m^3 \times 5,21 \times 10^{-5} \times 0,00046\ m/s}{0,8004 \times 10^{-3}\ \mathrm{Ns}/m^2}$

= 0,031 (memnuhi syarat $N_{RE} < 1$)

10. Kecepatan horizontal di bak (vh)

vh $= \frac{Qin}{2 \times \pi \times r \times h}$

$= \frac{0,022\ m^3/s}{2 \times \pi \times 3,9\ \mathrm{m} \times 3.5\ \mathrm{m}}$

= 0,00026 m/s

11. Jari-jari hidrolis (R)

R $= \frac{r \times h}{r + 2h}$

$= \frac{3,9\ \mathrm{m} \times 3,5\ m}{3,9\ \mathrm{m} + 2(3,5\ \mathrm{m})}$ = 1,26 m

12. Cek bilangan N_{Re}

N_{Re} $= \frac{vh \times r}{v}$

$= \frac{0,00026\ \mathrm{m/s} \times 1,26\ m}{0,8039 \times 10^{-6}\ m^2/s}$= 407 (memenuhi syarat <2000)

13. Cek bilangan Froude

N_{fr} $= \frac{vh}{\sqrt{g \times h}}$

$= \frac{0,00023\ \mathrm{m/s}}{\sqrt{9,81\ \mathrm{m}/s^2 \times 3,5}}$

= $3,93 \times 10^{-5}$ (memenuhi syarat $N_{fr} > 10^{-5}$)

14. Cek kecepata penggerusan/scouring (v_s)

K = Konstanta kohesi untuk partikel yang saling mengikat 0,06

F = Faktor friksi Darcy-Weisbach antara 0,02 – 0,03

vs > vh

vs $= \sqrt{\frac{8k(S-1).g.Dp}{f}}$

$= \sqrt{\frac{8 \times 0,06\ (1,25-1) \times 9,81\ \mathrm{m}/s^2 \times 5,21 \times 10^{-5}\ m}{0,03}}$

= 0,045 m/s (memenuhi syarat vs > vh)

- Zona inlet

1. Diameter inlet wall

D' = 20% × diameter bak

= 20% × 7,8 m

= 1,56 m

2. Kecepatan air di inlet wall

v $= \frac{Qin}{A}$

$= \frac{0{,}022\ m^3/s}{\frac{1}{4} \times \pi \times (1{,}56\ m)^2}$

= 0,0115 m/s

3. Pipa inlet

a. Luas penampang pipa

A $= \frac{Qin}{v}$

$= \frac{0{,}022\ m^3/s}{0{,}5\ m/s}$

= 0,044 m^2

b. Diameter pipa inlet

D $= \sqrt{\frac{4A}{\pi}}$

$= \sqrt{\frac{4 \times 0{,}044\ m^2}{\pi}}$

= 0,237 = 237 mm

Berdasarkan pipa yang ada di pasaran, didapatkan diameter sebesar **267 mm** atau **10 inch**

c. Cek kecepatan pipa inlet

v $= \frac{Qin}{A}$

$= \frac{0{,}022\ m^3/s}{\frac{1}{4} \times \pi \times (0{,}267\ m)^2}$

= 0,393 m/s

- Zona thickening

1. MLVSS dalam clarifier

Diasumsikan %*biological* yang tetap dalam bak activated sludge = 30%

Maka :

$MLVSS_{AS}$ = 30% × $MLVSS_{Total}$

= 30% × 2000 mg/l

= 600 mg/l

Sehingga MLVSS pada clarifier adalah sebesar:

$MLVSS_{Clarifier}$ = $MLVSS_{Total}$ – $MLVSS_{Clarifier}$

= 2000 mg/l – 600 mg/l

= 1400 mg/l

2. Massa solid total pada clarifier

$Massa_{solid\ total}$ = $MLVSS_{Clarifier}$ × $V_{Clarifier}$

= 1400 mg/l × 167.23 m^3

= 1400 g/m^3 × 167.23 m^3 = 234122 g

3. Kedalaman zona thickening

$$H = \frac{Massa\ solid\ total}{X \times A}$$

$$= \frac{234122\ g}{3000\ g/m^3 \times 47{,}78\ m^2} = 1{,}63\ m$$

- Zona sludge

1. Removal TSS

TSS_{re} = $TSS_{influen}$ × %Removal TSS

= 21,2 mg/l × 70%

= 14,84 mg/l

2. Berat solid = (Removal TSS × Qin) + Px MLSS

= (14,84 mg/l × 22 L/s) + 110,375 kg/hari

= 326,5 kg/hari + 110,375 kg/hari

= 436,875 kg/hari

3. Berat jenis solid = Ss × massa jenis air

= 1,25 × 995,7 kg/m^3

= 1244,63 kg/m^3

4. Volume solid $= \frac{berat\ solid}{berat\ jenis\ solid}$

$= \frac{436{,}875\ kg/hari}{1244{,}63\ kg/m^3}$

$= 0{,}35\ m^3$

5. Berat air $= \frac{95\%}{10\%} \times berat\ solid$

$= \frac{95\%}{5\%} \times 436{,}875\ kg/hari$

= 8300,625 kg/hari

6. Volume air $= \frac{berat\ air}{berat\ jenis\ air}$

$= \frac{8300{,}625\ kg/hari}{995{,}7\ kg/m^3}$

$= 8{,}34\ m^3$

7. Volume sludge = volume solid + volume air

$= 0{,}35\ m^3 + 8{,}34\ m^3$

$= 8{,}69\ m^3$

8. Berat sludge = volume Sludge × berat jenis sludge

$= 8{,}69\ m^3/hari \times 1030\ kg/m^3$

= 8950,7 kg/hari

9. Debit sludge $= \frac{berat\ sludge}{berat\ jenis\ sludge}$

$= \frac{8950{,}7\ kg/hari}{1030\ kg/m^3}$

$= 8{,}69\ m^3/hari = 0{,}0001\ m^3/s$

10. Dimensi ruang lumpur (sludge)

Volume lumpur $= 4{,}29\ m^3$

Asumsi waktu pengurasan = 1 hari

Jari-jari permukaan bawah = 1,26 m

Jari-jari Clarifier = 3,9 m

- Tinggi ruang lumpur (H)

  V sludge = Volume kerucut

  $8{,}69\ m^3 = \frac{1}{3} \times \pi \times H \times \left(R^2 + r^2 + (R^2 \times r^2)\right)$

  $8{,}69\ m^3 = \frac{1}{3} \times \pi \times H \times \left((1{,}26\ \mathrm{m})^2 + (3{,}9\ m)^2 + ((1{,}26\ \mathrm{m})^2 \times (3{,}9\ m)^2)\right)$

  H = 0,2 m

- H total clarifier

  H total = H settling + H thickening + H sludge

  = 3,5 m + 1,63 m + 0,2 m

  = 5,33 m

- Zona outlet

  Direncanakan

  - Menggunakan V notch dengan sudut 45°
  - Lebar v notch = 10 cm = 0.1 m
  - Jarak antar V notch = 40 cm = 0,4 m
  - Cd = 0,6
  - Q bak effluen = 0,012 m^3/s

  - Perhitungan

  1. Panjang pelimpah (weir)

     L = π × d bak

     = π × 7,8 m

     = 24,5 m

  2. Jumlah V notch

     n $= \frac{L\ weir}{Jarak\ antar\ weir}$

     $= \frac{24{,}5\ m}{0{,}5\ m}$

     = 49 notch

  3. Debit melalui V notch

     Q $= \frac{Q}{n}$

     $= \frac{0{,}012\ m^3/s}{49}$

     = 0.000245 m^3/s

  4. Tinggi limpasan melalui V notch

     Q $= \frac{8}{15} \times Cd \times \sqrt{2 \times g} \times \tan\theta \times H^{\frac{5}{2}}$

     0,012 m^3/s $= \frac{8}{15} \times 0{,}6 \times \sqrt{2 \times 9{,}81\ m/s^2} \times \tan 45° \times H^{\frac{5}{2}}$

H = 0,12 m

5. Saluran pelimpah

Direncanakan:

- Kecepatan aliran = 0,4 m/s
- Debit = 0,012 m^3/s
- Rasio (W:H) = 1:1

Perhitungan:

a. Luas permukaan saluran pelimpah (A)

A $= \frac{Q}{v}$

$= \frac{0{,}012\ m^3/s}{0{,}04\ m/s}$

= 0,03 m^2

b. Dimensi saluran pelimpah W : H = 2 : 1

A = W × H

= W × 2H

= $2W^2$

H $= \sqrt{2 \times A}$

$= \sqrt{2 \times 0{,}03\ \text{m}^2}$

= 0,25 m

W $= 2 \times H$

= 2 × 0,25 m

= 0,50m

Fb = 20% × H

= 20% × 0,25 m

= 0,05 m

Htot = H + Fb

= 0,25 m + 0,05

= 0,3 m

6. Pipa outlet ke badan air

Direncanakan:

- v = 0,4 m/s

- Q $= 0{,}012\ m^3/s$

- Luas penampang pipa

  A $= \frac{Q}{v}$

  $= \frac{0{,}012\ m^3/s}{0{,}4\ m/s}$

  $= 0{,}03\ m^2$

- Diameter pipa sludge total

  D $= \sqrt{\frac{4A}{\pi}}$

  $= \sqrt{\frac{4 \times 0{,}024\ m^2}{\pi}}$

  $= 0{,}195$ m

  Berdasarkan pipa yang ada di pasaran, didapatkan diameter sebesar 216 mm atau 8 inch

- Cek kecepatan pipa outlet

  v $= \frac{Q}{A}$

  $= \frac{0{,}012\ m^3/s}{\frac{1}{4} \times \pi \times (0{,}216\ mm)^2}$

  $= 0{,}328$ m/s

7. Pipa sludge total (diameter pipa inlet dari activated sludge)

   Direncanakan:

   - v $= 0{,}6$ m/s
   - Q $= 0{,}022\ m^3/s$

   - Luas penampang pipa

     A $= \frac{Q}{v}$

     $= \frac{0{,}022\ m^3/s}{0{,}6\ m/s}$

     $= 0{,}036\ m^2$

   - Diameter pipa sludge total

     D $= \sqrt{\frac{4A}{\pi}}$

$$= \sqrt{\frac{4 \times 0,036\ m^2}{\pi}}$$

= 0,214 m

Berdasarkan pipa yang ada di pasaran, didapatkan diameter sebesar 216 mm atau 8 inch

- Cek kecepatan pipa outlet

v $= \frac{Q}{A}$

$= \frac{0,022}{\frac{1}{4} \times \pi \times (0,216\ mm)^2}$

= 0,6 m/s

8. Pipa resirkulasi ke activated sludge

Direncanakan:

- v = 0,6 m/s
- Q = 0,01042 m^3/s

- Luas penampang pipa

A $= \frac{Q}{v}$

$= \frac{0,01042\ m^3/s}{0,6\ m/s}$

= 0,0174 m^2

- Diameter pipa sludge total

D $= \sqrt{\frac{4A}{\pi}}$

$= \sqrt{\frac{4 \times 0,02084\ m^2}{\pi}}$

= 0,148 m

Berdasarkan pipa yang ada di pasaran, didapatkan diameter sebesar 165 mm atau 6 inch merek

- Cek kecepatan pipa outlet

v $= \frac{Q}{A}$

$= \frac{0,01042}{\frac{1}{4} \times \pi \times (0,165\ mm)^2}$

= 0,49 m/s

9. Pipa sludge menuju SDB

Direncanakan:

- Q_{input} $= \frac{massa\ solid\ clarifier}{td}$

$= \frac{0{,}234122\ m^3}{3600\ s}$

$= 0{,}00065 + 0{,}0001\ m^3/s$

$= 0{,}00075$

- v rencana $= 0{,}5$ m/s

○ Luas penampang pipa

A $= \frac{Q}{v}$

$= \frac{0{,}00075\ m^3/s}{0{,}5\ m/s}$

$= 0{,}0025\ m^2$

○ Diameter pipa sludge menuju SDB

D $= \sqrt{\frac{4A}{\pi}}$

$= \sqrt{\frac{4 \times 0{,}0025}{\pi}}$

$= 0{,}056$ m

Berdasarkan pipa yang ada di pasaran, didapatkan diameter sebesar 60 mm atau 2 inch

○ Cek kecepatan pipa

v $= \frac{Q}{A}$

$= \frac{0{,}00075}{\frac{1}{4} \times \pi \times (0{,}060\ mm)^2}$

$= 0{,}3$ m/s

- Perhitungan pompa resirkulasi
  - Data perencanaan
    - ~ Elbow 90° suction = 3 buah
    - ~ Increaser suction = 1 buah
    - ~ Increaser discharge = 1 buah
    - ~ Q bak $= 0{,}01042\ m^3/s$

- ~ L suction = 34 m
- ~ L discharge = 3 m
- ~ Diameter pipa = 0,165 m => 6 inch
- ~ Kecepatan pipa = 0,35 m/s
- ~ Head statis = 4,51

- o Perhitungan

1. Perhitungan suction

a. Headloss mayor

Hf $= \left(\frac{Q\ pipa}{0{,}2875 \times C \times D^{2,63}}\right)^{1,85} \times L$

$= \left(\frac{0{,}01042\ m^3/s}{0{,}2875 \times 150 \times 0{,}165\ m^{2,63}}\right)^{1,85} \times$

$34\ m$

= 0,0579 m

b. Headloss minor (elbow 90°)

Hf $= n \times k \times \frac{v^2}{2 \times g}$

$= 3 \times 0{,}75 \times \frac{(0{,}35\ m/s)^2}{2 \times 9{,}81\ m/s^2}$

= 0,0413 m

c. ∑Hf suction = 0,0579 m + 0,0413 m

= 0,0992 m

2. Perhitungan Discharge

a. Headloss mayor

Hf $= \left(\frac{Q\ pipa}{0{,}2875 \times C \times D^{2,63}}\right)^{1,85} \times L$

$= \left(\frac{0{,}01042\ m^3/s}{0{,}2875 \times 150 \times 0{,}165\ m^{2,63}}\right)^{1,85} \times 3\ m$

= 0,0051 m

b. Headloss minor (elbow)

Hf $= n \times k \times \frac{v^2}{2 \times g}$

$= 1 \times 0{,}75 \times \frac{(0{,}35\ m/s)^2}{2 \times 9{,}81\ m/s^2}$

= 0,0138 m

c. ∑Hf discharge = Hf mayor + Hf minor

= 0,0051 m + 0,0138 m

= 0,0189 m

3. Perhitungan Head total = Head statis + ∑Hf suction + ∑Hf discharge

= 4,51 m + 0,0992 m + 0,0189 m

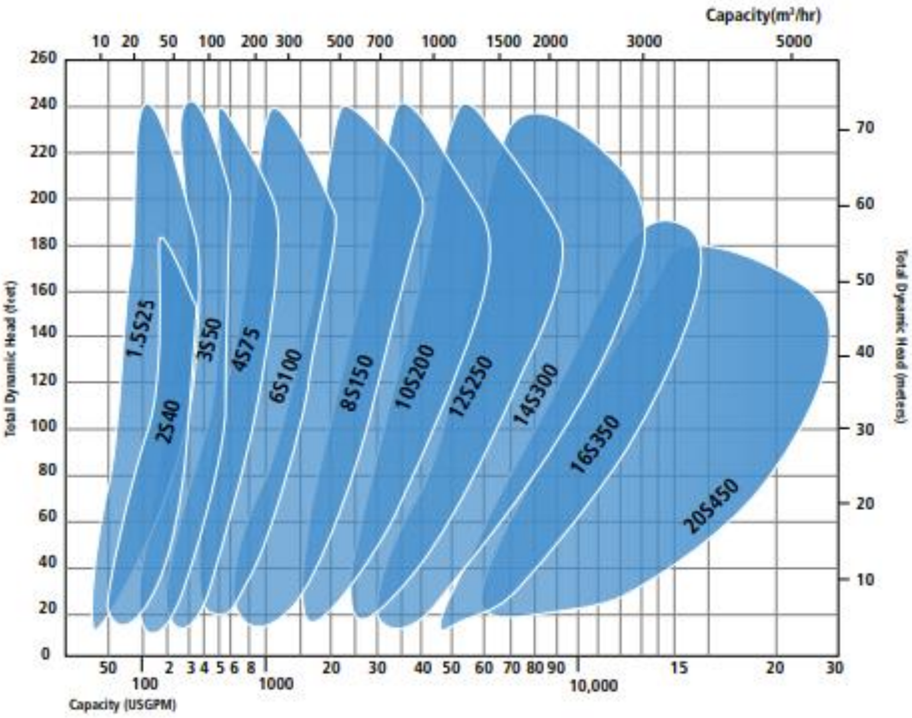
= 4,6280 = 4,63 m

4. Perhitungan Head pompa = 4,51 m + 34 m + 3 m

= 41,51 m

Head pompa > Head total

41,51 m > 4,63 m (memenuhi persyaratan)



Gambar 5.3 Grafik Pompa Resirkulasi Lumpur

Berdasarkan grafik di atas, maka dipilih pompa dengan merek Schurco Slurry Pump S Series tipe 1,5S25 dengan spesifikasi yang tertera pada lampiran A.

- Perhitungan pompa menuju SDB
  - Data perencanaan
    - Elbow 90° suction = 1 buah
    - Elbow 90° discharge = 0 buah
    - Increaser suction = 0 buah
    - Increaser discharge = 1 buah
    - Tee = 1 buah
    - Q bak = 0,000075 m^3/s
    - L suction = 8,5 m
    - L discharge = 22 m
    - Diameter pipa = 0,089 m => 3 Inch
    - Kecepatan pipa = 0,6 m/s
    - Head statis = 4,2
  - Perhitungan

    Perhitungan suction

    a. Headloss mayor

    Hf $= \left(\frac{Q\ pipa}{0{,}2875 \times C \times D^{2{,}63}}\right)^{1{,}85} \times L$

    $= \left(\frac{0{,}0075\ m^3/s}{0{,}2875 \times 130 \times 0{,}165\ m^{2{,}63}}\right)^{1{,}85} \times 12{,}5\ m$

    = 0,00330 m

    b. Headloss minor (elbow 90°)

    Hf $= n \times k \times \frac{v^2}{2 \times g}$

    $= 4 \times 0{,}75 \times \frac{(0{,}6\ m/s)^2}{2 \times 9{,}81\ m/s^2}$

    = 0,05505 m

    c. ∑Hf suction = Hf mayor + Hf minor

= 0,00330 m + 0,05505 m

= 0,05834 m

5. Perhitungan Discharge

a. Headloss mayor

Hf $= \left(\frac{Q\ pipa}{0,2875 \times C \times D^{2,63}}\right)^{1,85} \times L$

$= \left(\frac{0,0075\ m^3/s}{0,2875 \times 130 \times 0,165\ m^{2,63}}\right)^{1,85} \times$

$22\ m$

= 0,0058 m

b. Headloss minor (increaser)

Hf $= n \times k \times \frac{v^2}{2 \times g}$

$= 1 \times 0,25 \times \frac{(0,6\ m/s)^2}{2 \times 9,81\ m/s^2}$

= 0,0046 m

c. Headloss minor (tee)

Hf $= n \times k \times \frac{v^2}{2 \times g}$

$= 1 \times 1,25 \times \frac{(0,6\ m/s)^2}{2 \times m/s^2}$

= 0,0229 m

d. ∑Hf discharge = Hf mayor + Hf minor

= 0,0058 m + 0,0046 m + 0,0229 m

= 0,0333 m

6. Perhitungan Head total = Head statis + ∑Hf suction + ∑Hf discharge

= 4,5 m + 0,05834 m + 0,0333 m

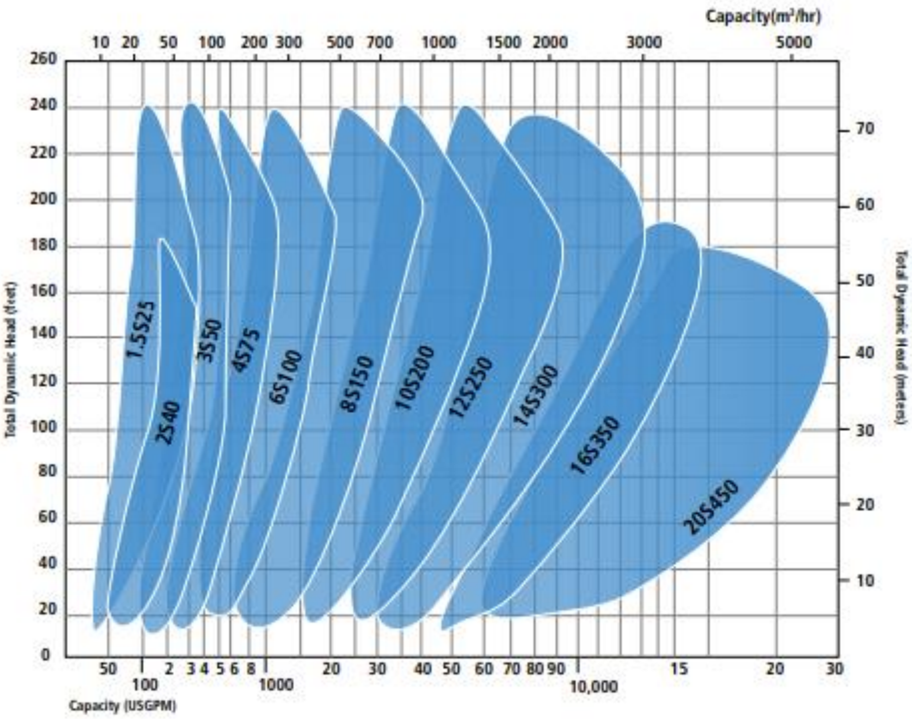
= 4,5917 m

7. Perhitungan Head pompa = 4,5 m + 12,5 m + 22 m

= 39 m

Head pompa > Head total

39 m > 4,5917 m (memenuhi persyaratan)



Gambar 5.4 Grafik Pompa Lumpur
Menuju SDB

Berdasarkan grafik di atas, maka dipilih pompa dengan merek Schurco Slurry Pump S Series tipe 1,5S25 dengan spesifikasi yang tertera pada lampiran A.

- Resume bangunan
  - Zona settling
    - ~ Diameter bak = 7,6 m
    - ~ Tinggi bak = 3,5 m
    - ~ Diameter inlet well = 1,52 m
  - Pipa inlet
    - ~ Diameter pipa inlet = 10 inch = 267 mm
  - Zona sludge
    - ~ Tinggi zona sludge = 0,5 m
    - ~ Tinggi thickening = 1,64 m
  - Zona outlet

- ~ Panjang pelimpah = 23,56 m
- ~ Jumlah V notch = 47 notch
- ~ Tinggi limpasan air = 0,12 m
- ~ Tinggi total saluran pelimpah = 0,3 m
- ~ Tinggi air saluran pelimpah = 0,25 m
- ~ Lebar saluran pelimpah = 0,48 m

o Pipa outlet

- ~ Diameter pipa outlet = 8 inch
- ~ Diameter pipa lumpur total = 10 inch
- ~ Diameter pipa lumpur resirkulasi = 6 inch
- ~ Diameter pipa lumpur outlet = 6 inch

5.10 Sludge Drying Bed

a. Kriteria Perencanaan

- Waktu pengeringan = 10 – 15 hari
- Tebal sludge cake = 20 – 30 cm
- Lebar = 23 – 30 cm
- Panjang = 11 m
- Slope = 6 – 30 m
- Kecepatan aliran pipa = > 0,75 m/s
- Berat air dalam cake (Pi) = 60% – 70%
- Kadar air (P) = 60% – 80 %
- Kadar solid = 20% – 40 %
- *Sludge loading rate* = 120 – 150 kg/solid kering/m2.tahun

(Sumber : Metcalf & Eddy, Wastewater Engineering Treatment & Reuse, Fourth Edition, hal 1570-1572)

b. Data Perencanaan

- Menggunakan 1 unit sludge drying bed dengan 4 bed + 1 bed maintance
- Volume lumpur total = bak pengendap + clarifier

= $23{,}8\ m^3 + 8{,}69\ m^3$

= $32{,}5\ m^3$

- Tebal pasir = 0,3 m
- Tebal kerikil = 0,3 m
- Tebal sludge cake = 0,3 m
- Waktu pengeringan = 10 hari
- Berat air dalam cake = 60%
- Kadar solid = 20%
- Kadar air (P) = 80%
- Freeboard = 10%

c. Perhitungan

1. Tebal media

   Tebal media = tebal pasir + tebal kerikil + tebal cake

   = 0,3 m + 0,3 m + 0,3 m

   = 0,9 m

2. Debit pipa inlet

   Qp = 0.00014 m^3/s + 0,0003 m^3/s

   = 0,00044 m^3/s = 38 m^3/hari

   Volume per hari = 38 m^3/hari × 1 hari = 38 m^3

3. Volume lumpur tiap bed

   Vb $= \frac{V\ lumpur\ total}{jumlah\ bed}$

   $= \frac{38\ m^3}{4}$

   = 9,5 m^3

4. Volume sludge cake (Vi)

   Vi $= \frac{Vb(1-p)}{1-Pi}$

   $= \frac{9{,}5\ m^3\ (1-80\%)}{1-60\%}$

   = 4,75 m^3

5. Volume sludge drying bed

   V = Vi × td

   = 4,75 m^3 × 10 hari

   = 47,5 m^3

6. Dimensi tiap bed

A $= \frac{V}{tebal\ cake}$

$= \frac{47{,}5\ m^3}{0{,}3\ m}$

= 158,3 m

W = 11 m

A = P × L

158,3 m^2 = P × 11 m

L = 14,4 m

7. Volume air

Va $= \frac{Vol\ lumpur\ total - (Vi \times td)}{jumlah\ bed}$

$= \frac{38\ m^3/hari - (4{,}75\ \ m^3/hari \times 1\ hari)}{4}$

= 11,1 m^3

8. Kedalaman underdrain

H $= \frac{Va}{A}$

$= \frac{11{,}1}{158{,}3}$

= 0,1 m

9. Kedalaman total

Kedalaman = H total media + H underdrain

= 0,9 m + 0,1 m

= 1 m

H Bangunan = H air + *freeboard*

= 1 m + (20% x 1 m)

= 1,2 m

10. Diameter pipa underdrain

Q $= \frac{Va}{td}$

$= \frac{11{,}1\ m^3}{3600\ detik}$

= 0,0031 m^3/s

A $= \frac{Q}{v\ rencana}$

$= \frac{0,0031}{0,6}$

$= 0,0052$

D $= \sqrt{\frac{4A}{\pi}}$

$= \sqrt{\frac{4 \times 0,0052\ m^3/s}{\pi}}$

$= 0,082$ m

Berdasarkan pipa yang ada dipasaran, didapatkan diameter sebesar 89 mm atau 3 inch

d. Resume

a. Jumlah bed = 3 buah
b. Tebal pasir = 0,3 m
c. Tebal kerikil = 0,3 m
d. Tebal Cake = 0,3 m
e. Panjang (L) = 7 m
f. Lebar (W) = 25 m
g. Tinggi total = 1,2 m
h. Diameter pipa underdrain = 1/2 inch