# FORMULAS - MANITOBA CERTIFICATION EXAMINATIONS
## *(Revised January 2006)*

## AREAS

| | |
|---|---|
| **Triangle**<br>Area ($m^2$) = ½ B x H<br>B = length of base (m)<br>H = height of triangle (m) | **Rectangle**<br>Area ($m^2$) = L x W<br>L = length of rectangle (m)<br>W = width of rectangle (m) |
| **Circle**<br>Area ($m^2$) = $\pi R^2 = \frac{\pi D^2}{4} = \frac{3.14 x D x D}{4}$ | $\pi$ = 3.14<br>R = radius (m)<br>D = diameter (m) |

## CIRCUMFERENCE

| | |
|---|---|
| **Circle**<br>Circumference (m) = $2\pi R$ or $\pi D$ or C = 3.14 x D | $\pi$ = 3.14<br>R = radius (m)<br>C = circumference(m)<br>D = diameter (m) |

## VOLUMES

| | |
|---|---|
| **Rectangular tank**<br>Volume ($m^3$) = area of base x H<br>or V = L x W x H | L = length of rectangle (m)<br>W = width of rectangle (m)<br>H = height of rectangle (m) |
| **Cylindrical tank**<br>Volume ($m^3$) = area of base x H<br>or V = $\frac{\pi D^2}{4}$ x H or V = $\pi R^2$ x H | $\pi$ = 3.14<br>D = diameter of base (m)<br>H = height of cylinder (m)<br>R = radius of base (m) |
| **Cone**<br>Volume ($m^3$) = 1/3 area of base x H<br>or V = 1/3 $\pi R^2$ x H<br>or V = 1/3 $\pi \frac{D^2}{4}$ x H = $\frac{1}{12} \pi D^2$ x H | $\pi$ = 3.14<br>R = radius of base(m)<br>D = diameter of base (m)<br>H = height of cone from base to apex (m) |
| **Prism**<br>Volume ($m^3$) = area of base of prism x H<br>or V = A x H | A = area of base of prism ($m^2$)<br>H = height or depth of prism (m) |
| **Sphere (ball)**<br>Volume ($m^3$) = $\frac{4\pi R^3}{3}$<br>or V = $\frac{4}{3} \pi \frac{D^3}{8} = \frac{1}{6} \pi D^3$ | $\pi$ = 3.14<br>R = radius of sphere (m)<br>D = diameter of sphere (m) |
| **Lagoon**<br>Volume ($m^3$) = $\frac{WxL + (W - 2SH)x(L - 2SH)}{2}$ x H | W = width of lagoon (m)<br>L = length of lagoon (m)<br>S = slope (ratio of horizontal to vertical distances on the interior sides of lagoon).<br>Example: 3:1, slope is taken as 3.<br>H= height of liquid or depth of liquid in lagoon. (m) |

## TIME

1 day = 24 hrs [or] 1440 minutes [or] 86,400 seconds

## TEMPERATURE

| | |
|---|---|
| Fahrenheit = $(°C \times \frac{9}{5}) + 32°F$ | Celsius = $(°F - 32°F) \times \frac{5}{9}$ |

## ABBREVIATIONS

| | | | |
|---|---|---|---|
| Em | motor inefficiency | m | metre |
| Ep | pump efficiency | $m^3$ | cubic metre |
| Hp | horsepower | mL | millilitre |
| kPa | kilopascal | L | litre |
| mg | milligram | ML | megalitre |
| g | grams | MLD | megalitre (1,000,000 L) per day |
| kg | kilogram | min/d | minutes per day |
| sq | square | | |

## METRIC CONVERSION FACTORS

### Metric Units

| | | | |
|---|---|---|---|
| 10 millimetres (mm) | = 1 centimetre (cm) | 1 000 millilitres (mL) | = 1 Litre (L) |
| 1 000 millimetres(mm) | = 1 metre (m) | 1 000 liters | = 1 cu. m ($m^3$) |
| 100 centimetres (cm) | = 1 metre (m) | 1 000 000 liters (L) | = 1 Megalitre (ML) |
| 1 dekametre (dam) | = 10 metres (m) | 1 milligram (mg) | = 1000 micrograms (ug) |
| 1 000 metres (m) | = 1 kilometre (km) | 1 gram (g) | = 1000 milligrams (mg) |
| 10 000 sq. m ($m^2$) | = 1 hectare (ha) | 1 kilogram (kg) | = 1000 grams (g) |
| 1 cu. meter (m3) | = 1,000,000 cu. cm ($cm^3$) | 1 000 kilograms (kg) | = 1 tonne (t) |
| 1 000 cu. cm ($cm^3$) | = 1 Litre (L) | 1 kilowatt (kW) | = 1000 watts |

*1 litre (L) of water weighs 1 000 grams = 1 kg*

*1 litre (L) of water weighs 1 000 000 milligrams = 1kg*

*1 cu. m ($m^3$) of water weighs 1000 kg*

*1 metre of hydraulic head (m) = 9.81 kPa*

## MEASURES OF CONCENTRATION

| | |
|---|---|
| 1 mg/L = 1 ppm (1 part per million) | 1 ppm = 1 part /1 million parts |
| 1 mg/L = 1 gram / $m^3$ | 1% = 10 000 mg/L |

## DETENTION TIME / RETENTION TIME

| | |
|---|---|
| Detention Time (seconds) = $\frac{Volume}{FlowRate} = \frac{V}{Q}$ | V = Volume ($m^3$)<br>Q = Flow Rate ($m^3$/s) |

## VELOCITY

| | |
|---|---|
| Velocity (m/s) = $\frac{Distance}{Time} = \frac{L}{T}$ | L = Length (m)<br>T = Time (s)<br>v = Velocity (m/s) |
| Velocity (m/s) = $\frac{Flow\,Rate}{Area} = \frac{Q}{A}$ | Q = Flow Rate ($m^3$/s)<br>A = Cross Sectional Area ($m^2$)<br>v = Velocity (m/s) |

## FLOW RATE

| | |
|---|---|
| **PIPE**<br>Flow Rate ($m^3/s$) = Area x Velocity<br>Q ($m^3/s$) = A x v | Q = Flow Rate ($m^3/s$)<br>A = Cross Sectional Area ($m^2$) $A = \pi \frac{D^2}{4}$<br>v = Velocity (m/s) |
| **CHANNEL**<br>Flow Rate ($m^3/s$) = Area x Velocity<br>Q ($m^3/s$) = (Width x Depth) x v<br>= (W x d ) x v | Q = Flow Rate ($m^3/s$)<br>A = Cross Sectional Area ($m^2$) A = W x d<br>W = Width of channel (m)<br>d = Depth of liquid in channel (m)<br>v = Velocity (m/s) |

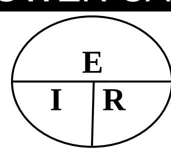
## OVERFLOW RATE / SURFACE LOADING RATE

| | |
|---|---|
| Clarifier Rise Rate ($m^3/m^2xd$) = $\frac{Q}{A}$<br>Weir Overflow Rate ($m^3/dxm$) = $\frac{Q}{WL}$ | A = Clarifier Surface Area ($m^2$)<br>Q = Flow Rate ($m^3/d$)<br>WL = weir length (m) |

## FORCE

| | |
|---|---|
| Force (Newtons) = (Volume x Density) x (Accel. of Gravity)<br>= (V x $\rho$ ) x g | V = Volume ($m^3$)<br>$\rho$ = density (kg/ $m^3$)<br>g = Acceleration of Gravity = 9.81 $m/s^2$ |
| Uplift Force (kilo-Newtons) = (Area x Height) x 9.81 kPa/m<br>= (A x H) x 9.8 1 | A = cross sectional area ($m^2$)<br>H = Liquid Depth (m) |

## POWER CALCULATIONS




| | |
|---|---|
| P = I $\times$ E<br>E = I $\times$ R<br>Water Power (kW) = $\frac{Q \text{ x } H}{6125}$<br>Water Horsepower (Hp) = $\frac{Q \text{ x } H}{4570}$<br>(This equation assumes 100% motor and pump efficiency) | P = Power (watts)<br>E = Voltage (volts)<br>I = Current (amps)<br>R = Resistance (ohms)<br>Q = flow rate (L/min)<br>H = head of water (m)<br>1 Hp (electric) = 0.7457 kW<br>1watt=1Joule/sec.<br>1 kW- hr =3.6MJ (Mega Joule) |
| Pump Power (W) = $\frac{Force \times Height}{Time} = \frac{F \times h}{T}$<br>Brake Power (kW) = $\frac{Q \text{ x } H}{6125Ep}$ = $\frac{\text{Water Power}}{\text{Pump Effic( Ep)}}$<br>Motor Power = $\frac{\text{Brake Power}}{\text{Motor Effic.(Em)}}$ = $\frac{\text{WaterPower}}{\text{(Ep) x (Em)}}$ | F = Force (N)<br>h = height of lift (m)<br>T = Time (s)<br>Ep = pump efficiency<br>This equation does not assume 100% motor or pump efficiency.<br>A pump efficiency (Ep) of 100% = 1<br>A motor efficiency (Em) of 100% = 1 |

## EFFICIENCY

| | |
|---|---|
| Overall Efficiency (%) = $\frac{\text{Output x 100}}{\text{Input}}$<br>Treatment Efficiency (%) = $\frac{\text{(Ci - Ce) x 100}}{\text{Ci}}$ | Ci = concentration in the influent<br>Ce - concentration in the effluent |

## CHEMICAL/ VOLUME REQUIREMENT

Volume 1 x Conc. 1 = Volume 2 x Conc. 2

$$V_1 \times C_1 = V_2 \times C_2$$

$V_1$ = Volume 1 (L)  $C_1$ = Concentration 1 (mg/L)

$V_2$ = Volume 2 (L)  $C_2$ = Concentration 2 (mg/L)

## CHEMICAL REQUIREMENT

$$CD\ (mg/L) = \frac{C(kg) \times 1\,000}{V(m^3)}$$

$$CD\ (mg/L) = \frac{C(kg/d) \times 1\,000}{Q(m^3/d)}$$

CD = Dosage (mg/L)
C = Mass of Chemical Added (kg or kg/d)
V = Volume ($m^3$)
Q = Flow Rate ($m^3$/d)

## CHEMICAL FEEDING

$$\text{Chemical Feed Rate (ml/min)} = \frac{CD \times Q}{c \times d \times 1440}$$

$$\text{Chemical Required (kg)} = \frac{\text{Pure Chemical}}{\text{\% Purity}}$$

*Note: Pure Chemical expressed in kilograms*
*% Purity expressed as a decimal*

CD = Dosage (mg/L)
Q = Flow Rate ($m^3$/d)
c = % active chemical expressed as a decimal
d = relative density of chemical feed (g/$cm^3$)

## CHLORINATION

Total Chlorine Dosage = Chlorine Demand + Chlorine Residual

Chlorine Residual = Combined Chlorine + Free Chlorine

## UNIT LOADING

$$\text{Flow Loading } (m^3/\text{day x cap}) = \frac{Q}{population}$$

$$\text{BOD Loading (kgBOD/d x cap)} = \frac{Q \times C}{population \times 1\,000}$$

Q = Flow Rate ($m^3$/d)
C = Concentration of BOD in the influent (mg/L)
Note: Population and Capita (cap) are similar

## FILTER YIELD (VACUUM)

$$\text{Yield } (kg/m^2 \text{ x h}) = \frac{(C/100) \times Q}{A}$$

C = concentration of solids in sludge feed (%)
Q = sludge feed rate to filter (L/h)
A = surface area of filter ($m^2$)
(This formula assumes there are no solids in the filtrate and the specific gravity of sludge is equal to water.)

## FILTER LOADING RATE

$$\text{Filter Loading Rate } (L/m^2xs) = \frac{Q \times 0.0116}{A}$$

*Note: If flow rate Q is in L/s then the equation is:*

$$\textit{Filter Loading Rate } (L/m^2xs) = \frac{Q}{A}$$

Q = flow rate ($m^3$/d)
A = surface area of the filter ($m^2$)

## FILTER BACKWASH RATE

$$\text{Method 1. Filter Backwash Rate } (L/m^2 \text{x s}) = \frac{Q}{A}$$

$$\text{Method 2. Filter Backwash Rate (m/h)} = \frac{R}{T}$$

Q = rate of upflow of backwash water (L/s)
A = surface area of filter ($m^2$)
R = water rise (m)
T = time (h)

## SOLIDS LOADING

Solids loading refers to the daily mass of suspended solids entering the clarifier or sedimentation basin.

| | |
|---|---|
| Solids Loading (kg /d) $= \dfrac{QxC}{1000}$ | Q = Flow of settled wastewater ($m^3/d$)<br>C = Solids Concentration of SS in settled sewage (mg/L) |

## ORGANIC LOADING

Organic loading of an aeration tank refers to the daily mass of BOD entering the aeration tank volume.

| | |
|---|---|
| Organic Loading, F ($BOD_5$ kg/d) $= \dfrac{QxC}{1000}$<br>Volumetric Organic Loading (kg BOD/$m^3$ x d) $= \dfrac{QxC}{Vx1000}$<br>*Note: Volumetric Organic Loading applies to Trickling filters.* | Q = flow of settled sewage to aeration tank ($m^3/d$)<br>C = concentration of BOD in settled sewage (mg/L)<br>V = volume of aeration tank ($m^3$)<br>F = organic loading ($BOD_5$ kg/d) |

## SLUDGE VOLUME INDEX

| | |
|---|---|
| $SVI = \dfrac{\text{volume of settled sludge x 1000}}{\text{MLSS}}$<br>$SVI = \dfrac{\text{volume of settled sludge (\%)}}{\text{mixed liquor suspended solids (\%)}}$ | MLSS = mixed liquor suspended solids (mg/L)<br>volume of settled sludge expressed in mL |

## SLUDGE DENSITY INDEX

| | |
|---|---|
| $SDI = \dfrac{100}{SVI}$ | SVI = sludge volume index |

## F/M RATIO

| | |
|---|---|
| $\dfrac{F}{M}$ ratio $= \dfrac{BOD_5\ kg}{MLVSS\ kg}$<br><br>$= \dfrac{Q \times B}{V \times VSS}$ | F = $BOD_5$ *kg/d* $= \dfrac{Q \times C}{1000}$<br>where Q = flow of settled wastewater ($m^3/d$)<br>C = $BOD_5$ concentration of settled sewage (mg/L)<br><br>M = MLVSS *kg* = mixed liquor volatile suspended solids MLVSS is assumed to be equal to the mass of microorganisms in the aeration tank<br>$= \dfrac{V \times VSS}{1000}$<br>where V = volume of aeration tank ($m^3$)<br>VSS = mixed liquor volatile suspended solids (mg/L) |

## RECYCLE RATE

$$Q_R = \frac{Q_E \times MLSS}{RSSS - MLSS}$$

$Q_R$ = return or recycle sludge flow rate ($m^3/d$)
$Q_E$ = effluent flow rate ($m^3/d$) (may be assumed to equal influent flow rate)

MLSS = mixed liquor suspended solids (mg/L)
RSSS = return or recycle sludge suspended solids (mg/L)

## SOLIDS RETENTION TIME (or Mean Cell Residence Time)

Solids Retention Time (SRT) or Mean Cell Retention Time (MCRT) is the length of time that biological solids are held within a process. SRT and MCRT is stated in days.

$$MCRT = \frac{(V_A \times MLSS) + (V_C \times MLSS)}{(Q_W \times WSSS) + (Q_E \times FESS)}$$

or in simplified form by omitting sludge in clarifier

$$SRT = \frac{V_A \times MLSS}{(Q_W \times WSSS) + (Q_E \times FESS)}$$

SRT = solids retention time in days
$V_A$ = volume of aeration tank(s) ($m^3$)
$V_C$ = volume of final settling tank ($m^3$)
$Q_W$ = daily waste sludge flow ($m^3/d$)
$Q_E$ = effluent (or influent) flow ($m^3/d$)
MLSS = mixed liquor suspended solids (mg/L)
WSSS = waste sludge suspended solids (mg/L)
FESS = final effluent suspended solids (mg/L)

## SLUDGE WASTING

$$\text{Waste Sludge Rate Required} = \frac{(M_1 - M_2) \times V}{R}$$

$M_1$ = present MLSS (mg/L)
$M_2$ = desired MLSS (mg/L)
V = volume of aeration tank ($m^3$)
R = suspended solids in sludge recycle or return (mg/L)

## RESPIRATION RATES

Oxygen Uptake Rate or Specific Uptake Rate (SUR)

$$\text{Oxygen Uptake Rate } (mgO_2/L \times h) = \frac{(DO_1 - DO_2) \times 60}{T}$$

Specific Uptake Rate = SUR ($mgO_2/h \times g$ MLVSS)

$$= \frac{\text{Oxygen Uptake Rate} \times 1000}{\text{MLVSS (mg/L)}}$$

$DO_1$ = dissolved oxygen in mixed liquor sample at start of test (mg/L)
$DO_2$ = dissolved oxygen in mixed liquor sample at end of test (mg/L)
T = duration of the test (min.)

Oxygen Uptake Rate = rate of oxygen utilization ($mgO_2$/hxg)

MLVSS = mixed liquor volatile suspended solids (mg/L)

## DIGESTER LOADING (volatile solids)

$$\text{Loading } (kg/m3 \times d) = \frac{C \times P \times Q}{V \times 10}$$

C = concentration of solids in sludge feed (%)
P = concentration of volatile solids in sludge feed (%)
Q = volume of sludge feed ($m^3/d$)
V = volume of digester ($m^3$)

## REDUCTION OF VOLATILE SOLIDS IN DIGESTER

$$\text{Reduction (\%)} = \frac{(P_I - P_D)}{P_I - (P_I \times P_D)} \times 100$$

$P_D$ = volatile matter in digested sludge (%)
$P_I$ = volatile matter in feed (raw) sludge (%)

# IMPERIAL - METRIC CONVERSION FACTORS

## Imperial Units

| | | |
|---|---|---|
| 1 mile | = | 5280 ft |
| 1 mile | = | 1760 yds. |
| 1 Imperial gallon of water | = | 10 lbs. |
| 1 cubic foot of water | = | 62.4 lbs. |
| 1 cubic foot of water | = | 6.24 Imperial gallons |
| 1 Imperial gallon | = | 277 cubic inches |
| 1 million gallons per day Imperial | = | 700 gallons per minute |
| 1 million gallons per day Imperial | = | 1.85 cubic feet per second |
| 1 cubic foot per second | = | 375 Imperial gallons per minute |

## Length Equivalents

| | | | | | |
|---|---|---|---|---|---|
| 1 kilometre | = | 0.621 mile | 1 mile | = | 1.61 kilometre |
| 1 metre | = | 3.28 feet | 1 foot | = | 0.305 metre |
| 1 metre | = | 39.37 inches | 1 inch | = | 0.0254 metre |
| 1 centimetre | = | 0.3937 inch | 1 foot | = | 30.5 centimetres |
| 1 millimetre | = | 0.0394 inch | 1 inch | = | 2.54 cm or 25.4 mm |

## Area Equivalents

| | | | | | |
|---|---|---|---|---|---|
| 1 $km^2$ | = | 247 acres | 1 $mile^2$ | = | 2.56 $km^2$ |
| 1 hectare | = | 2.47 acres | 1 acre | = | 0.405 ha |
| 1 $m^2$ | = | 10.765 $ft^2$ | 1 $ft^2$ | = | 0.093 $m^2$ |
| 1 $cm^2$ | = | 0.155 $in.^2$ | 1 $in^2$ | = | 6.45 $cm^2$ |
| 1 $ft^2$ | = | 929 $cm^2$ | | | |

## Volume Equivalents

| | | | | | |
|---|---|---|---|---|---|
| 1 kilolitre | = | 220.2 gallons | 1 gallon | = | 4.54 L |
| 1 L | = | 0.220 gallons | 1 quart | = | 1.135 L |
| 1 L | = | 0.881 quarts | 1 $ft^3$ | = | 28.317 L |
| 1 $m^3$ | = | 35.32 $ft^3$ | 1 $ft^3$ | = | 0.028 $m^3$ |
| 1 $cm^3$ | = | 0.061 $in^3$ | 1 $in^3$ | = | 16.387 $cm^3$ |
| 1 $m^3$ | = | 1.308 $yd^3$ | 1 $yd^3$ | = | 0.764 $m^3$ |
| 1 MG | = | 4.54 ML | 1 ML | = | 0.22 MG |

## Weight Equivalents

| | | | | | |
|---|---|---|---|---|---|
| 1 metric tonne | = | 1.103 tons | 1 ton | = | 0.907 tonne |
| 1 kg | = | 2.205 pounds | 1 pound | = | 453.6 gm |
| 1 gm | = | 0.035 ounces | 1 ounce | = | 28.35 gm |

## Velocity Equivalents

| | | | | | |
|---|---|---|---|---|---|
| 1 ft/sec | = | 0.305 m/sec | 1 m/sec | = | 3.28 ft/sec |
| 1 ft/sec | = | 305 mm/sec | 1 km/hr | = | 0.62 miles/hr |
| 1 mile/hr | = | 0.45 m/sec | 1 mile/hr | = | 1.61 km/hr |

## Pressure and Head Equivalents

| | | | | |
|---|---|---|---|---|
| 1 pound per $inch^2$ [psi] | = | 6.9 kPa | [or]2.31 ft | [or]0.704 m |
| 1 kPa | = | 0.145 psi | [or]0.328 ft | [or]0.1 m |
| 1 foot of hydraulic head [ft] | = | 0.433 psi | [or]3.05 kPa | [or]0.305 m |
| 1 metre of hydraulic head [m] | = | 1.43 psi | [or]9.81 kPa | |

## Flow Rate Equivalents

| | | | | | |
|---|---|---|---|---|---|
| 1 $ft^3$/sec | = | 28.3 L/s | 1 $m^3$/sec | = | 13212 gpm |
| 1 $ft^3$/sec | = | 0.028 $m^3$/sec | 1 $m^3$/sec | = | 35.32 $ft^3$/sec |
| 1 gpm | = | 0.076 L/s | 1 L/s | = | 13.2 gpm |
| 1 MGD | = | 4.54 MLD | 1 MLD | = | 0.220 MGD |
| 1 gpm/$ft^2$ | = | 0.81 mm/s | 1 mm/s | = | 1.23 gpm/$ft^2$ |
| 1 $ft^3$/sec | = | 375 gpm | | | |