UNIVERSITAT POLITÈCNICA DE VALÈNCIA

CAMPUS D'ALCOI

Process to obtain organic fertilizer from wastewater

ANNEX II: CALCULATIONS PRESENTED BY:

José Carlos Valls Arenas

MECHANICAL ENGINEERING DEGREE

Defence convocation: *September 2019*

1 CONTENT

Calculations

In the present project, different calculations are going to be done.

1. The amount of sludge produced by the wastewater treatment plant (WWTP).
2. Chose the right machines by catalogue according to the results obtained in the first calculations.
3. Chose the industrial plant by considering all the dimension of the machines and their plant layout.
4. Calculate the suitable compressor and air compressed grid.

1 SLUDGE PRODUCTION

According to “Plan Territorial Especial de Orientación de Residuos en Tenerife” the sludge production per capita is 0’455 kg per person each day, so the sludge production from a WWTP which treat 12.220 inhabitants is 2030 tons per year.

To make the numbers clearer, it is going to be calculated how many tons per day will receive the composting company and how many tons per hour will treat.

$$P=SP \times I \times 365 \div 1000 \quad (1)$$

$$P=0,455 \times 12200 \times 365 \text{ days} \div 1000 \text{ kg} =2030 \left(\frac{t}{year}\right).$$

Where:

P=Product in one year

SP= Sludge production.

I=Inhabitants.

The next step is to know how many tons are produced in one month

$$Pm=P \div 12 \text{ months} \quad (2)$$

$$Pm= 2030 \left(\frac{t}{year}\right) \div 12 \text{ month}= 169,17 \left(\frac{t}{month}\right).$$

Where:

Pm= Product per month

Now, considering the company works 24 days per month and only one turn per day. Product per day (Pd) is calculated:

$$Pd=Pm \times 1 \text{ month} \times 24 \text{ days} \quad (3)$$

$$Pd= 169,17 \left(\frac{t}{month}\right) \times 1 \text{ month} \div 24 \text{ days} = 7,05 \left(\frac{t}{day}\right).$$

Bearing in mind an average of 7 net hours produced by workers. Product per hour (Ph) is calculated:

$$Ph=Pd \times 1 \text{ day} \div \text{net hours} \tag{4}$$

$$Ph= 7{,}15 \left(\frac{t}{day}\right) \times 1 \text{ day} \div 7 \text{ hours}= 1{,}01 \left(\frac{t}{hour}\right).$$

After the first calculations, it is going to propose an installation which can works at least with 1 ton per hour.

2 MACHINERY

Now it is known that the company will manufacture 1 ton per hour so for each machine will be carefully reviewed in the company catalogue or in their specifications, that the machines fulfil this premise.

All the machines have been chosen by the author.

Following the order, they will treat the sludge to produce the fertilizer, the machines will be in the next sequence:

1. Crusher.
2. Mixer.
3. Compactor.
4. Dryer.
5. Cooler.
6. Screener.
7. Packaging machine.
8. Baler.
9. Pallet conveyor.

Then, will be mentioned all the needed accessories and machines such as belt conveyor or hoppers to connect the process and/or make it easier.

Crusher

- Model: AZS-LSFS-60.
- Company: AZEUS (Azeus Fertilizer Machinery).
- Dimensions: 1000x730x1700 mm (LxWxH).
- Capacity: 1-5 t/h.
- Motor power: 15 kw.

Mixer

- Model: M4000.
- Company: Sudenga Industries, Inc.
- Dimensions: 3580x1490x1956 mm (LxWxH).
- Capacity: 2 tones.
- Motor power: 15 HP = 11 kw.

Compactor

- Model: DZJ-II 1.0.
- Company: Zhengzhou Tianci Heavy Industry Machinery Co., LTD.
- Dimensions: 1060x950x1400 mm (LxWxH).
- Capacity: 1-2 t/h.
- Motor power: 15 kw.

Dryer

- Model: SD 60-18.
- Company: Baker Rullman.
- Dimensions: 5500 mm long x 1800 mm diameter.
- Capacity: 0,635-1,156 t/h.
- Motor power: 40 HP = 29 kw

Cooler

- Model: 1.5Φx10.
- Company: Inczk.
- Dimensions: 10000 mm long x 1500 mm diameter.
- Capacity: ≥1 t/h.
- Motor power: 15 kw

Screener

- Model: FY-GTSF-1.0x3.
- Company: FanWay Fertilizer Machinery.
- Dimensions: 3800x1300x2600 mm (LxWxH).
- Capacity: 1-3 t/h.
- Motor power: 3 kw.

Packaging machine

- Model: SJIII-K5000
- Company: IDDM GRUPO.
- Dimensions: 2300x2000x2350 mm (LxWxH).
- Capacity: 15-20 bag/min.
- Power: 3,5 kw.
- Air pressure: 75 psi = 5,71 bar.
- Air consumption: 7 L/min = 0,007 m^3/min.
- Electrical requirement: 220V/60Hz/monophasic.

Baler

- Model: Technoplat 3000
- Company: Control Pack.
- Dimensions: 2870x2010x2960 mm (LxWxH).
- Capacity: 1500 kg
- Installed potency: 3,5 kw.

- Electrical requirement: 220V/50-60Hz/monophasic.

Pallet conveyor

- Model: Personalized
- Company: Funcem S.L.U.
- Dimensions:15000 x1300x350 mm (LxWxH).
- Capacity: 2000 kg
- Installed potency: 1,00 kw.
- Electrical requirement: Triphasic.

After the specifications of the machines, now it is going to carry out the calculation by the catalogue of the complements to make the process continuous.

Complements

1. Forklift (x2).
2. Pallet truck (x2).
3. Turner machinery.
4. Tractor.
5. Shovel tractor.
6. Blowing nozzle(x8).
7. Truck scale.
8. Belt conveyor (x3).
9. Hopper (x2).
10. Elevator.
11. Endless conveyor (x3).

Forklift

- Model: Clark GTX 20 S.
- Company: CLARK the forklift.
- Dimensions: 2066x3159x2059 mm (LxWxH).
- Battery: 36V/26,8 kwh.
- Maximum height: 3970 mm.
- Load capacity: 2000 kg.

Pallet truck

- Model: GS.
- Company: Leroy Merlin.
- Dimensions: 1150x530x1160 mm (LxWxH).
- Load capacity: 2200 kg.

Turner machinery

- Model: TG 201.
- Company: Gujer Innotec AG.
- Dimensions: 2700x1300x1250 mm (LxWxH).
- Turner capacity: 300m^3/h.
- Pile dimensions: 2000x1000 mm (WxH).

Tractor

- Model: VIVID 400.
- Company: BCS VIVID.
- Dimensions: 2276x1384x1996 mm (LxWxH).
- Engine power: 25,5kw/35HP.

Shovel tractor

- Model: Pauny PA120.
- Company: Pauny.
- Dimensions: 5870x2190x2995 mm (LxWxH).
- Engine power: 87HP/64kw.
- Shovel Capacity: 1,2 m^3.

Blowing nozzle

- Model: 27102 MB20.
- Company: Prevost.
- Air consumption: 14,5 Nm^3/h.
- Air pressure: 6 bar.

Belt conveyor

- Model: Standard.
- Company: RK taller metalúrgico.
- Dimensions: 4000x400x4500 mm (LxWxH).
- Motor power: 5 HP/3,73kw.

Hopper

- Model: Customized.
- Company: Talleres Joaquín.
- Dimensions: 5500x4000x4000 mm (LxWxH).
- Power: 4 kw.
- Production rate: 1 to 5 t/h.

Elevator

- Model: ZH-CZ1.
- Company: Hangzhou Zon Packaging Machinery Co., Ltd.
- Dimensions: 4000x1500x6000 mm (LxWxH).
- Electrical requirement: AC 380V/220V.
- Power: 0,55kw.
- Production rate: up to 2,5 m^3/h.

Endless conveyor

- Model: LS-125.
- Company: Xinxiang Sanyuantang Machine Co., Ltd.
- Dimensions:10500x2000x1000 mm (LxWxH).

- Endless degree: α=20º.
- Power: 3,5 kw.
- Production rate: 4,0 m^3/h.

2.1 JUSTIFICATION OF THE SELECTED MACHINES

After calculations, the machines must fulfil the premise of producing 1 ton per hour (as it was calculated and mentioned above).

While searching the machines, the author has met the following situations.

1. The machine does not achieve the minimum production rate.
2. 2 models can process 1 t/hour.
3. Same production rate, different companies.
4. Production rate, much higher than 1 t/hour.

What are the decisions the author had to make?

- In the first case, the machine is completely discarded.
- In the second case, if both achieve the production rate, it has been chosen the one that has a higher production rate.
- The third case, both machines have the same production rate, the discarded one was the most expensive.
- The production rate is much higher than 1 t/hour and there are smaller models, then it is considered the smaller models. If there were not smaller machines, the company is discarded and searched for another one.

The chosen machines are all described in the report.

3 COMPOSTING AREA

Something that needs to be calculated is the composting area and it is an important parameter to take into account to choose the industrial plant.

Its importance comes from the need to keep the sludge at least for 8 weeks to be able to process it and transform into organic fertilizer.

For this process, the author has calculated the space to accommodate 12 weeks of sludge, and the reason is to avoid problems in case there is lack of product from providers.

It has been applied for the whole process and the reason to choose this method to tread the sludge in comparison with the other methods, it is because this is more natural, the other available methods use technology that makes the process less organic and less respectful with the environment.

If it was not possible to know which method was more organic, it has been chosen the most typical process to carry out the transformation of the material.

The decisions mentioned in the section 2.1 do not interfere with this decisions.

Following step is to show the calculations made to know the necessary space for the composting area.

$$Tp = Ty \div 4 \qquad (5)$$

Where:

Ty: Tons per year

Tp: Period of 3 months

Tp= 507 tons

It is known that 1 m^3=0,5 tons of sludge.

So, 507 tons are equal to 1014 m^3.

Now, it is required to know how many space it is necessary to harbor all the sludge.

Pile size:

$$Tp = H \times A \times L/2 \times n \qquad (6)$$

H: Hight of the pile = 1 m.

A: Base of the pile = 2 m.

n: Number of piles = 20

L: Length, needs to be found.

After calculations, L= 51m

So now it is needed to know how much space these piles needs.

$$W = n \times 2 + 30 \qquad (7)$$

Where:

W: width of the whole piles.

M= 70.

So at least, the company needs to have an exterior space of 3.780 m^2

Finally, the composting area in the company will have 4079 m^2.

4 INDUSTRIAL PLANT

Next step is to choose the desired industrial plant, and for that has been considered parameters such us, machines dimensions and place where to put the sludge.

The industrial plant is in PL POLIGONO 7 RUSTICA 134, 28813 TORRES DE LA ALAMEDA (MADRID).

The plans from the industrial plant are able in the Annex_III_Plans

5 COMPRESSED AIR INSTALLATION

The calculation of the compressor and the compressed air grid is going to be based on the book: Aire comprimido from Enrique Carnicer Royo.

There is a factor that is very important to take into account and is that the compressed air is exposed to constant contamination:

1. From the aspired air: gases, the dust and the humidity.
2. From the compressor: metal particles and the lubricant.
3. Compressed air grid: possibility to find obstructions

5.1 CONCEPTS

5.1.1 Important concepts.

Pressure loss

It is important to consider the pressure that the machine needs, it is not the one that the compressor will generate (from the compressor it must be higher) because there is loss of pressure between the compressor to the machine. This loss cannot be avoided but must be reduced to the minimum (not being higher than 0.6 bar) to have an efficient system.

Utilization coefficient

It is the percentage of the time that the machine is working (page 198).

In this case:

Blowing nozzle → 10%

Packaging machine → 95%

Simultaneous coefficient

It is the probability of having the tools working at the same time (page 199).

In this project is being considered that the fertilizer process is in the group of:

- Other constructions, which has a simultaneous coefficient between 20 to 25 %.

Between 20 to 25 % it is going to be chosen the most unfavourable one, 25%.

The decision made above is going to be done in all the calculations, it means that if there is a range to make the calculations, it will always be chosen the unfavourable one.

5.1.2 Key parameters

The main parameters to do the installation are:

1. Pressure.
2. Flow.
3. Pressure lose.
4. Speed circulation.

The calculation for the desired compressor.

- First, it is important to be sure that the calculations are being done with the specific consumption, which includes the pressure with the machine will work.

Formula:

$$Q= Q_1 \times \frac{p+1,033}{1,033} \tag{8}$$

Where:

- Q= Air litres or cubic metres per minute.
- Q_1= Air litres or cubic metres per minute.
- P= Air pressure in bars. (page 16)
- Q_t=total consumption

The sum of the all consumptions is: Q_t= 1,979 (Nm3/min).

Now, the simultaneous coefficient (Q_s) must be applied:

Formula:

$$Q_s=0,25xQ_t \tag{9}$$

Q_s= 0,49 (Nm3/min).

This simultaneous consumption does not take into account losses due to leakage and possible company expansion which are parameters that must be included as it is mentioned in the book (page 208).

Losses → 10%

Expansion → 25%

Q_{ts}: simultaneous consumption considering the losses and the possible expansion.

Formula:

$$Q_{ts}= Q_s + 10\%\ Q_s +25\%\ Q_s \tag{10}$$

Q_{ts}= 0,67 (Nm3/min).

Now is time to calculate the compressed air grid.

For the calculation of the grid, it must be considered the pressure drop.

Formula:

$$\Delta p = \frac{\beta}{RT} \text{ x } \frac{V^2}{D} \text{ x Lp} \tag{11}$$

Where:
Δp= Pressure drop in bar.
β= Resistance index.
R= Gas constant, 29,27 for the air.
T= Absolute temperature (t + 273).
V= Air speed in m/second.
D= Interior pipe diameter in mm.
L= Pipes length in m.
p= Pressure in bar (page 217).
Now, it is going to be checked which data is known, and which one needs to be calculated to obtain the pressure drop Δp.

β: needs to be calculated.
R: 29,27.
T: (15+273).
V: from the book, it is known that the maximum speed is 15 m/second.
D: needs to be calculated.
L: can be obtained from the plan.
p: 6 bar.

For D.

Process to obtain the diameter:

- Knowing the speed formula is:

$$V = \frac{Q \ x \ 1000}{60 \ x \ p \ x \ A} \tag{12}$$

- And the diameter can be calculated from the area:

$$D = \sqrt{\frac{4 \ x \ A}{\pi}} \tag{13}$$

So:

- Q will be obtained:

For this Q it will be considered the utilization coefficient and the leakage losses for each machine.
  - Q_P, for the packaging machine.
  - Q_B, from the blowing nozzle.
- A will be clear from the speed formula.
- A will be input in D formula.

For β.

To obtain β it is needed to go through a formula to know the amount of air supplied, and a table given by Carnicer.

Formula:

$$G = 1{,}3 \times Q_p \times 60 \tag{14}$$

The table can be found in the page 217, Table 13.1.

Now it is possible to know the pressure drop in the installation, making sure that the losses are not higher than 2% (page 217).

So, if the pressure in the system is 6 bar, $\Delta p \leq 0{,}12$ bar. It is possible to say that the installation is correct.

After the calculations, the result is $\Delta p = 0{,}07$ bar so it complies with the requirements.

Calculations:

To know the compressor

	Initial Data	
	Packaging machine	Blowing nozzle
Number	1	8
Pressure (bar)	5,71	6
Air consumption (m^3/min)	0,007	0,035
Specific consumptions (Nm^3/min)	0,046	0,242
Total specific consumption (Nm^3/min)	0,046	1,933
All specific consumption (Nm^3/min) [Q_t]	1,979	

* Following the steps in Arroyo's book to know the plant consumption:

Simultaneous coefficient	25%
Simultaneous consumption (Nm^3/min) [Q_s]	0,49

Leakage lose	10%
Company expansion	25%
Total consumption (Nm^3/min) [Q_{ts}]	0,67

Total consumption [Q_{ts}]

It's the consumption that the compressor must be able to produce to have a good and continuous process in the plant.

Q_{ts} can be expressed also like: Q_{ts}= 99 (l/ min)

Calculations for the compressed air grid

	Machine	
	Packaging machine	Blowing nozzle
Specific consumptions (Nm3/min)	0,046	0,242
Total specific consumption (Nm3/min)	0,046	1,933
Utilization coefficient [U_c]	95%	10%
Consumption (Nm3/min) [Q_m]	0,043	0,193
All consumption (Nm3/min) [Q_t]	0,237	

* Counting the losses for leakage.

	Machine	
	Packaging machine	Blowing nozzle
Consumption (Nm3/min)	0,043	0,193
Leakage loses	10%	10%
Final consumption (Nm3/min)	0,048	0,213
Total final consumption (Nm3/min)	0,260	

*Necessary data to calculate the losses.

	Machine	
	Packaging machine	Blowing nozzle
Speed (m/s)	15	15
Pressure (bar)	6	6
Consumption (Nm^3/min)	0,048	0,027
Area (cm^2)	0,076	0,042
Diameter [Di] (mm)	3,106	2,318

Pipe	Principal	1 Nozzle	2 Nozzle	3 Nozzle	4 Nozzle	5 Nozzle	6 Nozzle	7 Nozzle	8 Nozzle	Machine
De (mm)	20	20	20	20	20	20	20	20	20	20
Di (mm)	17,4	17,4	17,4	17,4	17,4	17,4	17,4	17,4	17,4	17,4
Length (mm)	136000	2000	2000	2000	2000	2000	2000	2000	2000	1500
Pressure (bar)	6	6	6	6	6	6	6	6	6	6
Temperature (ºC)	15	15	15	15	15	15	15	15	15	15
Consumption (Nm3/min)	0,260	0,027	0,027	0,027	0,027	0,027	0,027	0,027	0,027	0,048
Pipe area (cm2)	2,4	2,4	2,4	2,4	2,4	2,4	2,4	2,4	2,4	2,4
Speed (m/s)	2,61	0,27	0,27	0,27	0,27	0,27	0,27	0,27	0,27	0,48
G (kg/hour)	20	2	2	2	2	2	2	2	2	4
β	1,83	2,57	2,57	2,57	2,57	2,57	2,57	2,57	2,57	2,36
Pressure drop (bar)	0,07	0,0	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
									Δp=	0,07