# Logical Math Problem Solving

Solving mathematical word problems is often an obstacle for an operator in the quest to achieve higher certification.

In all certification programs the operator must pass a test — and as any operator will tell you, there are math problems on the test and the higher the certification level is, the more complex the math problems become.

Most people find word problems the most difficult.

These types of questions usually can't be solved by plugging numbers into a single formula because there is no single "super formula" that can be used for word problems. Solving such problems takes a structured approach. Using a structured approach, long or complex problems can be broken down into simpler, solvable pieces.

A word problem is more than just a simple question. It presents several pieces of information about a situation, then asks a question related to that situation. Sometimes it presents more information than is needed to answer the question and it falls to the operator to; as the saying goes, separate the wheat from the chaff.

**A Typical Word Problem**

A wastewater treatment plant has three primary clarifiers, three aeration basins, and three secondary clarifiers. Waste activated sludge is thickened in a DAF and then pumped to a holding tank where it mixes with unthickened primary sludge. Mixed sludge from the holding tank is pumped to two solid bowl centrifuges.

Dry polymer (23 kg bags, $6.10 per kg) is made into a 0.6% solution in a day tank. The polymer solution is pumped into the mixed sludge feed line just prior to the centrifuge inlet.

Dewatered solids collect in 15 $m^3$ capacity hoppers and are composted or disposed of at the regional landfill at a cost of $120 per wet ton.

Currently, the plant is sending an average of 227 $m^3$ per day of mixed sludge to the centrifuges at a solid's concentration of 2.5%. Each of the two centrifuges is rated to receive 272 kg of mixed sludge per hour, and both are run at the same time.

If one centrifuge breaks down, how many more hours per week will the other one have to be operated to sustain the dewatering process?

**The Wrong Approach**

This problem gives us a brief description of a plant, some information about its sludge handling process, and cost information related to polymer used in the centrifuge.

The question gives us a little bit more information about the centrifuges and then asks about run time.

If you haven't been trained in solving word problems, your instinct might be to start crunching on the data given in the problem.

For example, if you find that the first two pieces of information in the first sentence are a flow and a concentration, you might use the "kg formula" to come up with a result. Then, go to the next sentence and calculate what you can from it, and so on, until you have gone through all the data.

This is unstructured problem solving.

You are using the data and producing results, but they might not be relevant to the question asked. In the example problem, the first bit of information given is about polymer and how it is dosed but ultimately the question is about centrifuge run time.

**Working Backwards**

A better way to attack a word problem is to work backwards. First, read through the problem to get a sense of what it's all about. If parts seem confusing, read it a couple of times, but don't worry about how to solve it just yet.

Now focus on the question. What is it asking specifically? Try to compare the question to a task you have done in real life. What information did you need to solve your real-life example? What will you need to solve it now?

The key is to start with the question. In our example, the question is asking for hours of run time. Now, reread the problem looking for bits of information that relate to time. In the example, there are two items related to time.

- One is the feed rate, which is in kilograms per hour,
- The other is the feed flow, which is in $m^3$ per day.

Let's focus on the kilograms per hour information.

The feed rate is the number of kilograms of mixed sludge fed to the press per hour. Intuition suggests that if we can calculate the number of kilograms of sludge, we ought to be able to calculate hours based on the feed rate. We should instinctively think of the kilogram formula at this point. For that, we use concentration and flow. This leads us to read the problem again but looking for sludge concentration and flow information. Sure enough, the information is there.

Now we can see how we can use the sludge concentration and flow information, the centrifuge loading rate, and somehow find the answer to the question.

**Using Units as Clues**

You may have noticed that we focused on units while working through the example. For solving the problem, numbers are not important until the end. We use units to figure out what is needed and how the pieces of information relate.

Time units are easily related since we can convert minutes to hours or seconds as needed. If we're given L/s, that can be converted to $m^3$ per hour without trouble.

Another clue that can be found in the units given in a problem is the word per, as in $m^3$ per hour. The word per almost always means "divided by."

If a unit is $m^3$ per hour, the number of $m^3$ are divided by the number of hours

Even with clues to lead you, word problems can be made very difficult. Including unnecessary information is one way to complicate a problem. For example, information about pH and dissolved oxygen might be put into a word problem that asks about aeration basin detention time. Often this is done to test whether the test-taker knows which measurements are proper for the calculations.

One aspect of solving word problems is realizing that sometimes some information can safely be ignored. Be careful about this, however. Some information might not be used in formulas but may still be needed to determine what formulas are applicable.

**Putting it to Paper**

Once we've figured out how to solve the problem, it's time to write down the answer.

Showing your work will make it easier for you to check for mistakes. The problem should be written out from start to finish, the reverse of how we solved it above. The bits of information should be generated by calculations step by step, with the results from one being used in the next as needed.

**Let's solve the problem**

Currently, the plant is sending an average of 227 $m^3$ per day of mixed sludge to the centrifuges at a solid's concentration of 2.5%. Each of the two centrifuges is rated to receive 272 kg of mixed sludge per hour, and both are run at the same time. If one centrifuge breaks down, how many more hours per week will the other one have to be operated to sustain the dewatering process?

Step 1: Convert percent (%) solids to mg/L.

We know that 1% = 10,000 mg/L and thanks to the beauty of the metric system it is also equal to 10 g/L or 10kg/$m^3$

$$2.5\% \times \frac{10{,}000\, mg/L}{1\%} = 25{,}000\, mg/L$$

Or

$$2.5\% \times \frac{10\, kg/m^3}{1\%} = 25\, kg/m^3$$

Step 2: Calculate how many kilograms of solids are contained in 227 m3 of sludge

$$\frac{25{,}000\, mg}{L} \times \frac{1{,}000L}{m^3} \times \frac{227m^3}{day} \times \frac{1\, kg}{1{,}000{,}000mg} = 5{,}675\, kg/day$$

Or

$$\frac{25\, kg}{m^3} \times \frac{227m^3}{day} = 5{,}675\, kg/day$$

The question tells us that one centrifuge can process 272 kg of solids per hour. We have calculated that 5,675 kg per day need to be processed. With these two pieces of information, we can calculate the centrifuge runtime.

Step 3: Calculate centrifuge runtime:

$$\frac{5{,}675\ \ kg/day}{272\, kg/hour} = 20.86\, hours/day$$

Or

$$\frac{5{,}675\, kg}{day} \times \frac{1\, hour}{272\, kg} = 20.86\, hours/day$$

But the problem states that two centrifuges are run simultaneously. So, we can calculate that each centrifuge must run:

$$\frac{20.86\ hours}{2} = 10.43\ hours/centrifuge/day$$

We now have enough information to answer the questions which was "*how many more hours per week will the other one have to be operated to sustain the dewatering process*"

Step 4: Calculate the additional run time for a single centrifuge

$$\frac{10.43\ hours}{day} \times \frac{7\ days}{week} = 73.01\ hours/week$$

A single centrifuge would need to operate an additional 73.01 hours per week to process the same amount of sludge as two centrifuges operating simultaneously.

Q: How does a person eat an elephant?

A: One bite at a time.

Math word problems are solved the same way and now you know how to approach them.