# Superabsorption: polymers, foams...


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# Super Absorbent Polymers- SAP

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Appendix 1- Where in the Syllabus ..... **Errore. Il segnalibro non è definito.**

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# Experiment 1 - Superabsorbing polymers

## *Experimental Goal*

The aim of this experiment is to study super absorbing polymers (SAP) behaviour.

Is SAP a good material for indoor cultivation on a spaceship or in hostile environment? Could it be a valuable tool in the fight against desertification? And, on the other side, to regulate excess of moisture in soil?

What's the life cycle of the beads? Do they lose in efficiency with repeated cycles?

First students will tackle the questions by plotting average diameter of the jelly beads VS time and calculating the water absorption and water release rate. What's the best model for the radius growth? Is the growth rate constant? If not why? What's the maximum capacity of the beads as water reservoirs?

Then a more in depth study will evaluate the impact of varying parameters on absorption, growth and retention: ph and salinity of the solution, different types of liquid and environmental variables such as temperature, and humidity.

Finally the optimal mix of earth and polymer is investigated with the use of Arduino and a soil humidity sensor + more environmental sensors +heated green house.

The study is conducted with the use of microcontrollers and sensors. This last part is much more time consuming and spread over time, therefore it is more suitable for individual research and high school students interdisciplinary final thesis .

## *The Experimental setup*

You need a ruler, camera (smartphone camera should be ok), small water containers and the polymer beads (you can buy them either online or at the florist's)

This is great stuff for home labs!

## *Part 1*

## *Data collection*

Put a few beads in abundant water, consider that the beads will increase their volume a lot so you really need a bowl full of water! You may use just one bead, but if you use several of them it will be a good exercise in averaging [1]. At the selected intervals take them out and after careful mopping put them next to the ruler and take an aerial snapshot from above. Then put the beads back iton the water till next measurement. After three measurements in a row without varying value you may think that the bead has stopped growing having reached the maximum absorption capacity. The first part of the experiment over.

Use Tracker Video Analysis Software (or similar tools) to analyse the snapshots and obtain the diameter measurements. The ruler will act as reference. In a more straightforward way just ask

[1] In alternativa inserire ad intervalli


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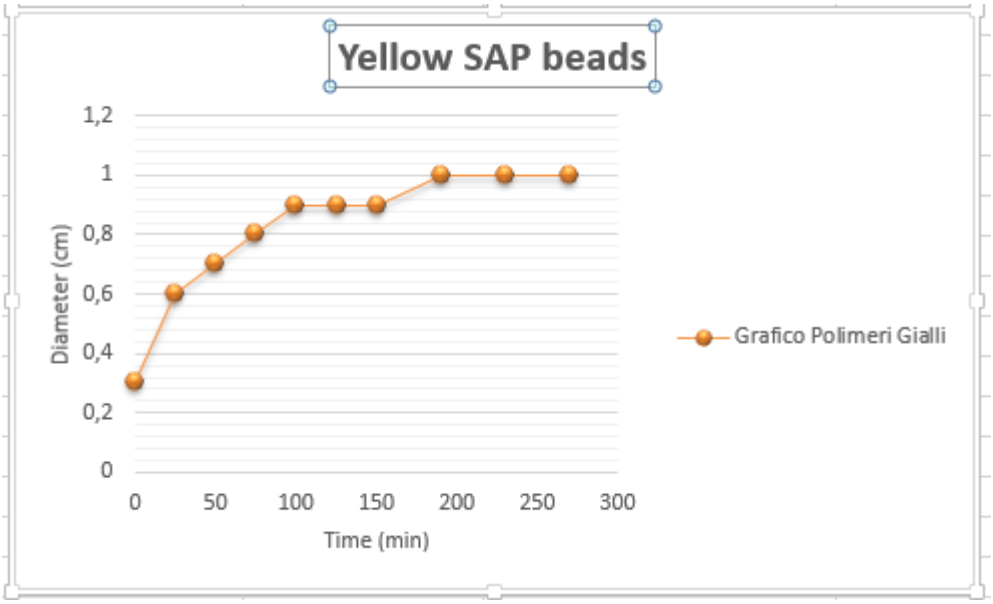
the students to zoom the pictures and measure with a ruler both the diameter and 1 cm in the reference ruler, then build and solve the related proportion.

*Data analysis*

Plot the bead diameter versus time and find a suitable growth model. Calculate the growth rate (volume %).




N.B. We used an Excel sheet for data analysis although from a scientific point of view this may not be the best option. However the software is easy to manage, well known to students who have it or a similar one (Open office)at home. This is the Excel data sheet:

| | A | B | C | D | E | F | | |
|---|---|---|---|---|---|---|---|---|
| 1 Initial diameter = … (mm) | Time (min) | Diameter 1 (mm) | Diameter 2… (mm) | Average Diameter (mm) | Diameter Growth Rate (mm/s) | absorption % | Mass (g) | Density (g/mm$^3$) |
| 2 | | | | | | - | | |
| 3 | | | | | | =(d2-d1)/$d$1 | | |
| 4 | | | | | | | | |

Notice that as radius increases the area increases as $r^2$ and volume as $r^3$

Since absorption is a surface issue the larger the surface the more the absorption. Is that true?

Plot the growth rate (either radius or volume) VS the surface area.

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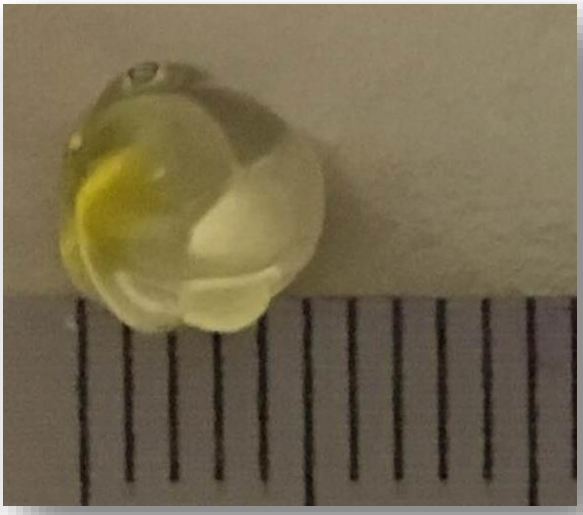
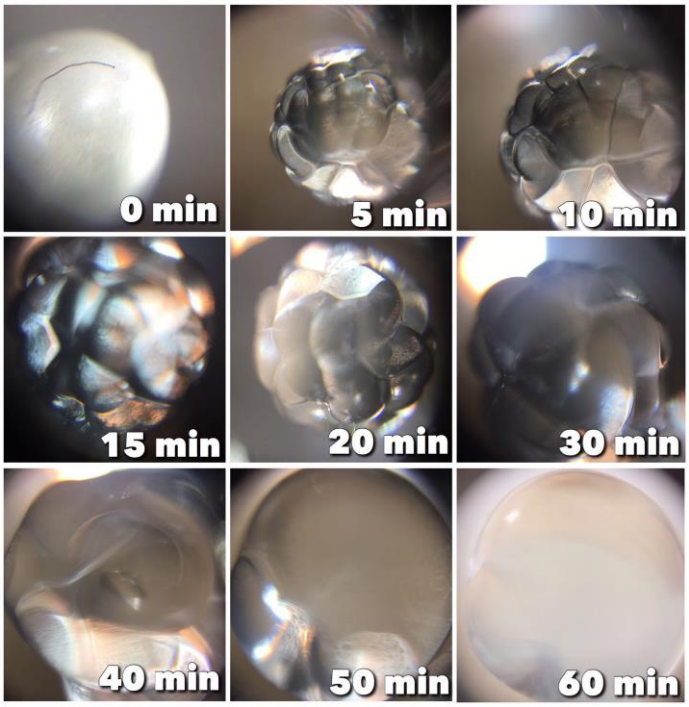
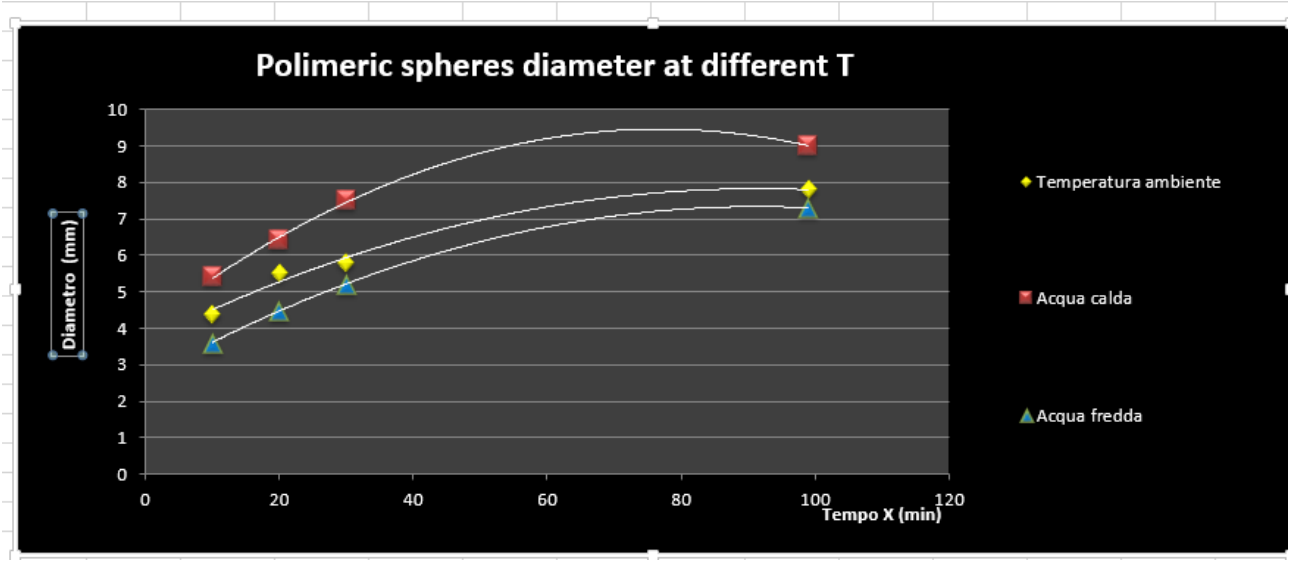





Actually if you look at the sphere surface under a microscope you can compare the sphere to a crumpled paper sheet, which means that the actual surface is larger than the spherical one. So we may suppose that the growth will be faster at the beginning to stabilize later on once the stretched sheet of paper




exactly matches the spherical surface.

We may assume that the two effects may combine to produce an almost constant growth.

| | A | B | C | D | E | F | | |
|---|---|---|---|---|---|---|---|---|
| 1 Initial diameter = … (mm) | Time (min) | Average diameter | Surface ($mm^2$) | Surface Growth Rate (mm/min | Volume ($mm^3$) | Volume Growth Rate (mm/min) | Mass (g) | Density ($g/mm^3$) |

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| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 2 | | | | | | - | | |
| 3 | | | | =(c2-c1)/$c$1 | | =(e2-e1)/$e$1 | | |
| 4 | | | | | | | | |

**Plot surface VS time and volume VS time**

**More questions** – Does it depend on

- the polymer orginal shape? (spheres VS cubes)
- water temperature? Put the beads in water with different temperatures (keep them at constant temperature inside thermal bottles)
- On salinity (distilled VS tap water, salted water at different concentrations), on Ph[2]? ….
- Type of liquid? Oil, Juice, milk, coca cola,,,,

Above you can see the resulting plot of the average bead diameter VS time. We plotted also the best fitting curve. Does the best fitting curve exhibit a correlation coefficient which is definitively good?

## *Part 2-Ph and other parameters dependence*

### *Data collection*


What about different liquids? Oil, alchool, sparkling water, water, different ph (this may be very important since soil may have very different ph (vinegar, bicarbonate + water) … Will they absorb with a similar rate?

and what about the dependence from environmental variables such as temperature, air humidity, wind???pressure? etc) we used a small green house with controlled temperature.

[2] While nonionic hydrogels are almost insensitive to pH changes, ionic hydrogels display a dramatic change in size with the pH change

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## *Part 3-Water retaining aid in agriculture*

### *Data collection*

As a follow up we want to investigate the **release rate** of the beads (how fast they shrink when you take them out of the water and leave them in the air?) This is a bit more tricky since it is heavily influenced by the surrounding environment. Therefore you will also have to record environmental parameters such as air temperature, humidity, and most of all you should be able to keep them constant

To simplify we will leave the beads in a closed lab/room so we may consider the dependence on air flow as irrelevant (although this is of course not true)

Take the full grown beads and put them next to the ruler. Take photos at constant intervals. You may consider the experiment over when the bead is back to the original dimension or will not shrink any longer.

Plot iameter versus time and, in a different graph the corresponding temperature and humidity VS time.,

.

### *Data analysis*

Plot the bead diameter versus time and find a suitable growth model. Calculate the shrinking rate (volume %).

## *Part 3- Application- Race to Mars- growing food in space*

Collaborative problem solving with the goal of producing relevant open-source solutions to address global needs applicable to both life on Earth and life in space.

Raeding1- growing food in space challenge (would microgravity affect the humidity release???)

Reading 2- Climate change challenge- fighting desertification.

## *Further Research*

### *Data collection*

In part 2 data was taken in full air. Now we will mix beads with soil. Have four samples with different percentages of beads and soil for two different kinds of soil ( for a total of 8 samples).

Monitor soil humidity and temperature VS time plotting results for the different samples in the same chart for quicker comparison.

For this third part of the experiment we suggest the use of a microcontroller driving multiple humidity and temperature probes and recording+saving data in real time\

**Even more questions…:**

- What's the bead freezing point? Same as water?
- Could the beads be used to absorb water + fertilizer and release it later in the soil?
- Could the beads be used to harvest water overnight in condensation regime (for instance places where you have thick fog? Maybe in conjunction with superhydrophobic water harvesting nets? Try with the humidifier

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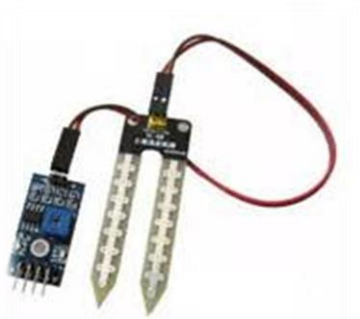
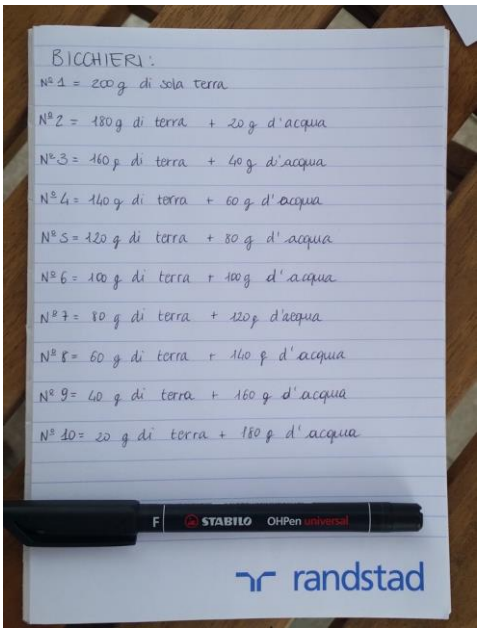
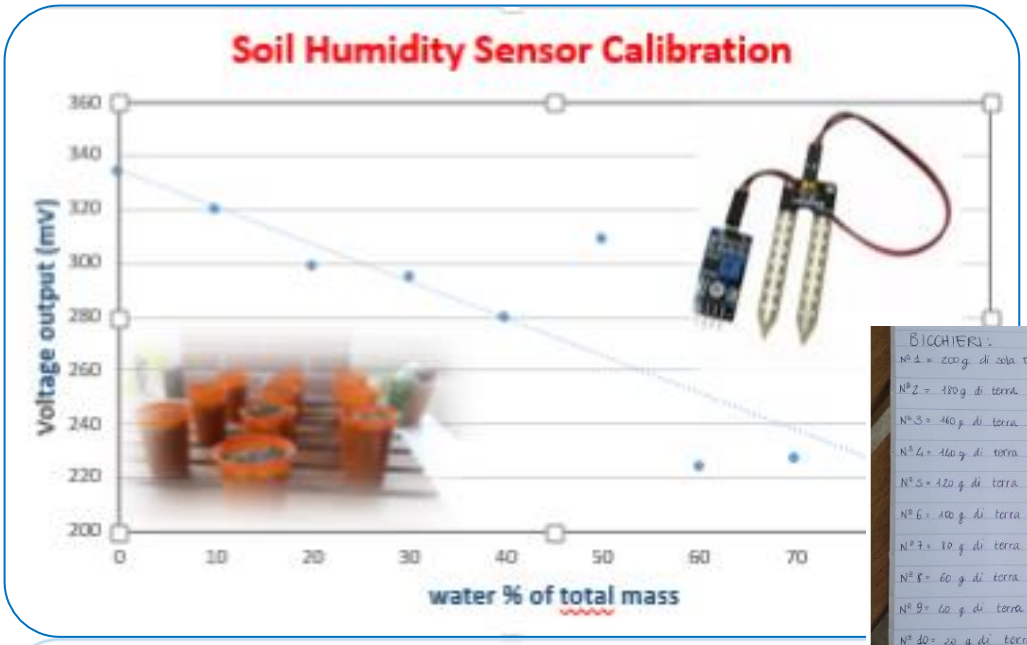
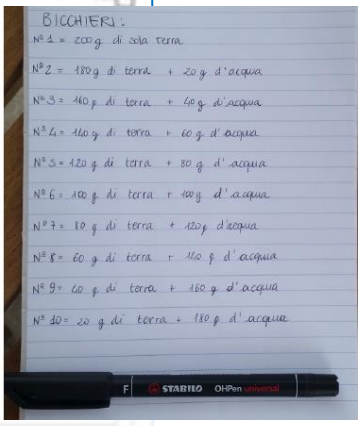
*The humidity sensor*



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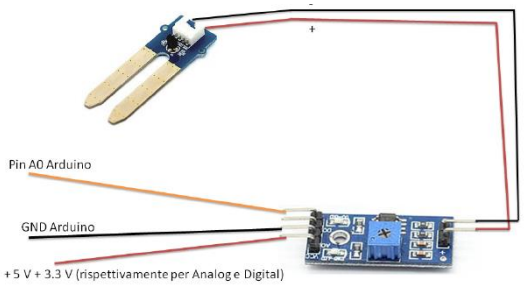
## The Sketch for the humidity sensor+LED

```
/*Sketch per rilevare l'umidita' del terreno (valore analogico) e accendere un led se si raggiunge una soglia critica. */
/* lo sketch usa un if ripetuto prima controlla se il valore è sopra 450 se lo è procede a controllare se è anche sopra 950, in tal caso accende il rosso
se invece non lo è (cioè è tra450 e 950) accende il verde) altrimenti se non era sopra 450 accende direttamente il blu*/
const int soglia_critica1 = 450; //Soglia alla quale il led sarà ON perchè il terreno sarà troppo bagnato
const int soglia_critica2 = 900; //Soglia alla quale il led sarà ON perchè il terreno sarà troppo arido

void setup()
{
  Serial.begin(9600);
  pinMode(9, OUTPUT); //led red
  pinMode(4, OUTPUT);// led blue
  pinMode(6, OUTPUT); //led green
}
void loop()
{
  int sensorValue = analogRead(A0); //if the value is <450 (critical level 1) then blue on; if the  >900(criticallevel 2) red; intermediate green
  Serial.println(sensorValue); //show on the serial monitor
  if (sensorValue >= critical level 1)
     {if (sensorValue >= critical level 2)
        {digitalWrite(9,HIGH);  //turn the red LED on
         digitalWrite(6, LOW); //keep blue and green off
         digitalWrite(4, LOW);
        }

      else  {
           digitalWrite(6,HIGH); //Turn on the green LED
           digitalWrite(9,LOW);
           digitalWrite(4,LOW);// keep off or turn off blue and red
     }
  else {
           digitalWrite (4,HIGH);// Turn on blue
           digitalWrite(9,LOW); // keep off or turn off green and red
           digitalWrite(6,LOW);
       }
  delay(2000); //wait for 2 sec and repeat
}
```

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## MoM Resources

1. Water wars Presentation : MoM_PRESENT_Wednesday_Water Wars.pptx
2. Hydrogel_Home Labs_1_2_3_IT-def.docx
3. Polygrowth video MOM_Polygrowth_VIDEO
4. MOM_Superabsorber_EN-pdf

## References

1. Food in Space (IT)http://www.esa.int/ita/ESA_in_your_country/Italy/ESA_Euronews_Coltivare_cibo_nello_spazio._Realta_o_fantascienza
2. Solid rain against draught http://www.bbc.com/news/science-environment-23715031 (VIDEO BBC)

## Where to buy materials and equipment

- The green house on Amazon- see picture above
- SAP are sold at florists (and also on Amazon) plus you can find them in specialized agricultural shops

## Credits

http://nestsrl.it/it/prodotti/polygreen.html

http://nestsrl.it/it/

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