

Workshop: seawater stratification.

In this workshop we use real profiles of water salinity, temperature and dissolved oxygen (CTD) measured by Latvian Institute of Aquatic Ecology during the environmental monitoring cruises in the Baltic Sea and the Gulf of Riga.

Each student selects from the database in MS Excel format one profile.

1 Task

Calculate the water density (ρ [kg/m³]) in all measured depths taking into account water temperature, salinity, and pressure (depth).

For a precise calculation you would use the water state equation. It is rather complicate. Several seawater density calculators may be found on the web (try to google 'sea water density calculation'). Regrettably these calculators do not disclose what kind of algorithm is being used. For the purpose of this exercise we will use a simplified formula from <http://mason.gmu.edu/~bklinger/seawater.pdf> :

$$\rho_{T,S,p} = C_p + \beta_p \times S - \alpha_{T,p} \times T - \Upsilon_{T,p} \times (35 - S) \times T$$

where:

$$C = 999.83 + 5.053p - 0.048p^2$$

$$\beta = 0.808 - 0.0085p$$

$$\alpha = 0.708(1 + 0.35p + 0.068(1-0.0683p)T)$$

$$\Upsilon = 0.003(1 - 0.059p - 0.012(1-0.064p)T)$$

P = depth (km)

S = salinity (‰)

T = Temperature (°C)

Copy the formulae used for calculation for the first worksheet into the worksheet of your profile. Use relative addressing of variables. By copying formulae into all rows of the profile table, calculate water density ρ (kg/m³) for each depth.

2 Task

Create a graph of the selected profile denoting the temperature (T) by a red line, salinity (S) by a blue line and density ρ by a black line. You may render the depth on the X axis, and T, S and ρ on the Y axis. If you are an expert Excel user you may also try to build the graph in the traditional way: depth on the vertical axis increasing downward from the top (axis intersection). In order to draw water density in the same scale as T and S, you will need to calculate so-called σ_T (sigma-T).

$$\sigma_T = \rho_{T,S,\rho} - 1000$$

3 Task

Analyse visually the graphs you produced. How many layers of the water density „jump” (pycnoclines) you observe? Which of the parameters: T or S causes these pycnoclines? What is the average water density in the mixed upper layer above the pycnocline and below it? At what depths you would place the upper and lower borders of the pycnocline layer? How many metres thick would the pycnocline layer then be? Notice that the upper border of pycnocline usually is clearly visible in the graph while the lower border is much more „smothered”.

4 Task

Assess the level of water column vertical stability by use of the Brunt-Vaisala frequency (N [rad/s]). Strictly speaking, N is the angular velocity of rotation. In order to calculate the frequency (number of oscillations per second) in the common understanding, we have to divide N by the number of radians in a full circle *i.e.* by 2π . For better comprehension we may calculate the period of the ‘inner waves’ (τ [s]). Smaller the τ , stronger is the vertical stability of the water column.

$$N = \left(\frac{g}{1000} \times \frac{\Delta\rho}{\rho} \right)^{1/2}$$

And

$$\tau = 2\pi/N$$

where:

g = gravitational acceleration 9.8 m/s^2

$\Delta\rho$ = gradient of water density in the pycnocline layer (kg/m^3)

Δz = thickness of the pycnocline layer (m)

$$\pi = 3.14$$

5 Task (if we have enough time, you may do it also at home)

Add to the previously created graph the data on concentrations of dissolved oxygen (mlO_2/l). Find out if there is oxygen deficiency at any of the depths of your profile. In hydrobiology the oxygen concentration of $2.5 \text{ mlO}_2/\text{l}$ is regarded as the oxygen deficiency border concentration. It is used e.g. for calculation of the reproduction volume of Atlantic cod (*Gadus morhua callarias*) in the Baltic Sea. Try to explain which bio-geo-chemical processes govern the vertical gradient of dissolved oxygen.