# MATHEMATICAL SALINITY DISPERSION MODEL ALONG BOSPHORUS

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## ABSTRACT

For the environmental evaluation, salinity levels control the type of plants and animals that can live in different zones of the estuary. Neutron activation analysis method is proposed to measure the salinity of seawater samples irradiated in neutron source (Howitzer Pu-Be source). Neutron Activation Analysis is applied to determine the salinity of Sea of Marmara and Bosphorus samples also the seasonal salinity dispersion along Bosphorus is mentioned with basic salinity dispersion model which is an exponential function.

**Key Words**: Salinity, Sodiumchloride, Sea of Marmara, Bosphorus

## INTRODUCTION

There are many techniques for the determination of salinity. These are routine, alternative and new developing methods to measure the salinity, but their sensitivity and applicable capacity can change due to their characteristics. Salinity can be measured either by physical or chemical methods. Physical methods use conductivity, density and refractivity measurements. They are generally quicker and more convenient than the chemical methods. The chemical methods determine chlorinity (Cl concentration) which is closely related to salinity.

Salinity fluctuates with the movement of tides due to dilution by precipitation and the mixing of the water with the wind. Many processes that have significant socio-economic impacts depend critically on salinity. These include but are not limited to biological effects on ecosystem function (e.g., oyster disease, nursery grounds, coastal wetlands, corals), development of harmful algal blooms (i.e., salinity as a habitat barrier), survival of invasive species (e.g., via discharged ballast water). In addition to such biological considerations, many purely physical processes depend on salinity (Woody et al., [1]).

Neutron Activation Analysis is an analytical technique based on the measurement of characteristic gamma rays emitted by isotopes of the sample that are produced by

irradiation with thermal neutrons. Neutron capture is followed by emission of a gamma, a particle or fission. Neutron capture frequently produces a radioactive reaction product with a characteristic half-life. This process is referred to as neutron activation. The induced activity persists after termination of neutron irradiation. Nearly all elements are capable of radioactive neutron capture (n,γ) with the emission of a prompt or delayed gamma from the excited nucleus (Hallenbeck, [2]).

$$_{11}Na^{23} + n \rightarrow {}_{11}Na^{24} + E_{\gamma}$$

Chemical methods use chlorine concentration to determine the salinity. With neutron activation analysis, chlorine concentration determination is not practical because of it has a very short half life ($t_{1/2}$=37.24m). Instead of chlorine, sodium is preferred to be used to determine the salinity because it is major element of salinity constituents and it has appropriate half life ($t_{1/2}$=14.95h).

## EXPERIMENTAL STUDIES

Bosphorus is chosen as the sample region because of the variety of the salinity. As known, Bosphorus connects Black Sea and Sea of Marmara and also through Eagean Sea. In Bosphorus, more salty Mediterranean seawater meets with less salty Black Sea seawater. In other words, Mediterranean seawater is diluted through Bosphorus. Therefore, Bosphorus is a salinity transition location.

For the surface search of salinity, all of the samples were collected from surface and stored in polymer storage bottles. Sample locations in Bosphorus (B1,B2,B3,B4,B5) can be seen in Fig. 1.

The residue samples and reference sample were irradiated in Howitzer (Pu-Be neutron source) for one half-life. The irradiated samples and the reference sample were counted within a 5 cm thick lead cell with a NaI(Tl) scintillation detector. The results were taken from a multichannel analyzer. Using Equation (1), the salinity (S) of the samples is determined.

$$S(g\ kg^{-1}) = \zeta\ \eta\ \xi\ .\ 1000 \qquad (1)$$

where,

*sample factor* (ζ), which is the ratio of the net count for the irradiated sample to mass of it

*reference factor* (η), that is the ratio of the mass of the irradiated reference sample to irradiated reference net count

*residue factor* (ξ), which is the ratio of the total sample residue mass to total evaporated water mass

The salinity results are shown in Table 1. The Neutron Activation Salinity results are compared with the literature values (Karaaslan, [3])

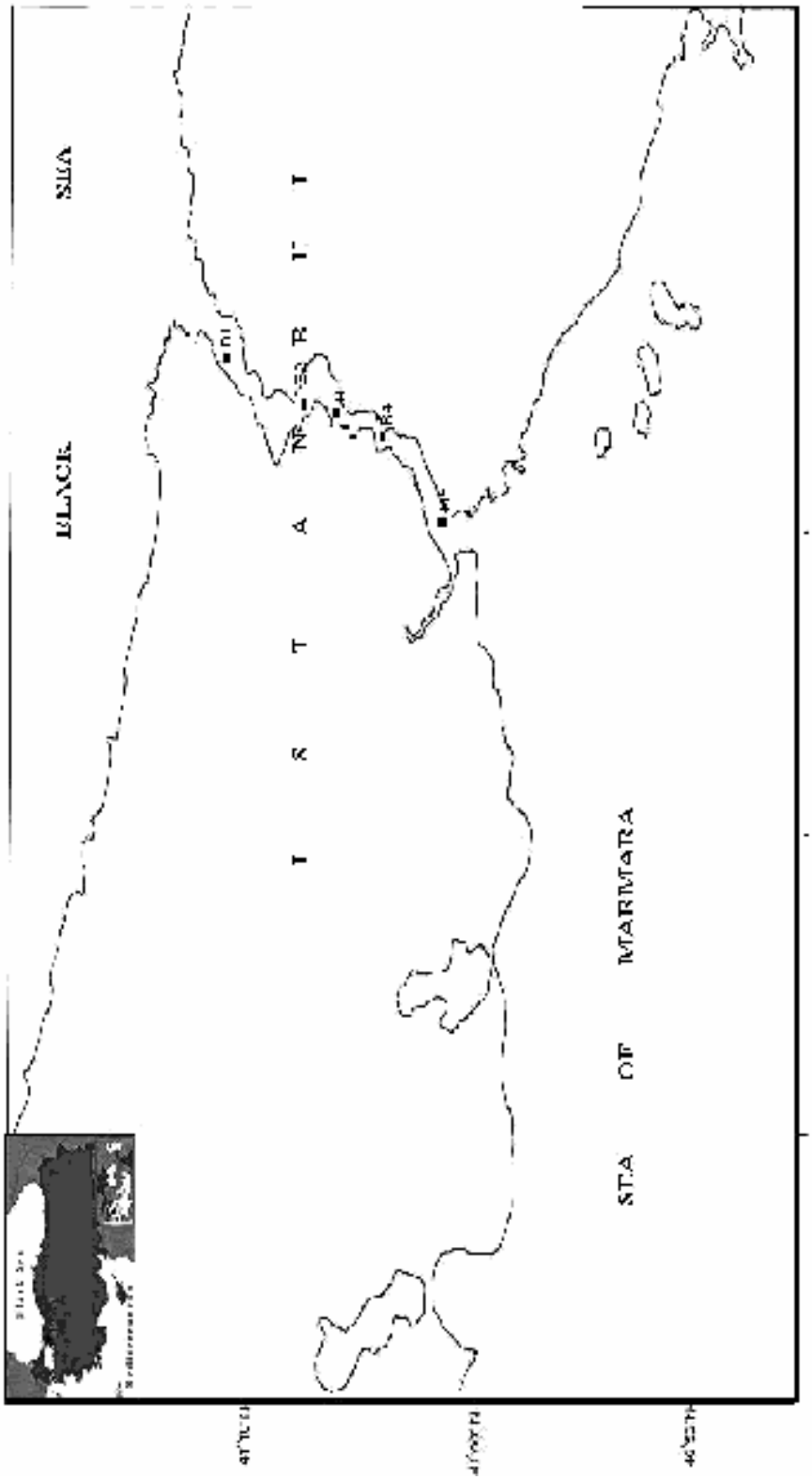


**Figure1. Sampling Location in Bosphorus**

## SALINITY DISPERSION MODEL

Bosphorus is the channel where the Black Sea water (S<17 $gkg^{-1}$, Black Sea has an average salinity of 22 $gkg^{-1}$) moves on the top and Mediterranean water underlies towards the Black Sea (Özsoy et al, [4]). Mediterranean water comes through first Eagean Sea, then Dardanelles Staitand finally to Marmara Sea. Marmara Sea water is diluted thorough Bosphorus or Black Sea water gets more salty thorough it. The dispersion of Black Sea water can be formularized as follows.

$$S = S_0 \exp(\beta x/L) \tag{2}$$

where,
S: salinity at the desired location on Bosphorus
$S_0$: Black Sea water salinity in the desired season (literature)
x : The distance of the desired location from the Black Sea entrance of Bosphorus (km)
L: Length of Bosphorus (km)
β: dispersion parameter (0.47)

The experimental results and the dispersion model results are shown in one graph for each season. The graphs covering one year (May 2002 – May 2003) are given in Figure 2 - Figure 5. The experimental and theoretical results suits with each other. The percentage error of experimental salinity results to Black Sea entrance model is 3.078% which is in the error approximation of the experimental results.

## RESULTS AND DISCUSSION

Counts were taken with care for many times. Salinity of the samples and their standard deviation for Neutron Activation Analysis were calculated by using Eq. (1). It can be said that the salinity increase from north to south along Bosphorus. The results are like what we expected because Black Sea has an average salinity of 17 g $kg^{-1}$ and Sea of Marmara 24 g $kg^{-1}$ (Bayazıt et al., [5]). The experimental and model results are shown in graphs as Figure 2 - Figure 5.

**Table1. Comparison of the Salinity Results with Different Measuring Methods for Bosphorus Samples of Surface (Karaaslan, [3])**

| Sample Location | Season | Salinity (g kg$^{-1}$) with NAA | Salinity (g kg$^{-1}$) Literature Values (Bayazıt, [5]) |
|---|---|---|---|
| B1 | Fall | 16.67±0.30 | ~17.00 |
| B2 | Fall | 18.04±0.33 | ~18.00 |
| B3 | Fall | 18.65±0.31 | ~18.00 |
| B4 | Fall | 19.11±0.29 | ~19.00 |
| B5 | Fall | 20.26±0.30 | ~20.00 |
| B1 | Winter | 16.01±0.27 | ~16.00 |
| B2 | Winter | 17.35±0.29 | ~17.00 |
| B3 | Winter | 17.48±0.26 | ~17.00 |
| B4 | Winter | 18.07±0.25 | ~18.00 |
| B5 | Winter | 19.19±0.25 | ~19.00 |
| B1 | Spring | 17.78±0.24 | ~17.00 |
| B2 | Spring | 18.92±0.26 | ~18.00 |
| B3 | Spring | 19.15±0.26 | ~19.00 |
| B4 | Spring | 20.12±0.23 | ~20.00 |
| B5 | Spring | 20.61±0.25 | ~20.00 |
| B1 | Summer | 18.86±0.78 | ~ 18.00 |
| B2 | Summer | 19.12±0.75 | ~ 18.00 |
| B3 | Summer | 20.40±0.77 | ~ 19.00 |
| B4 | Summer | 20.75±0.84 | ~ 19.00 |

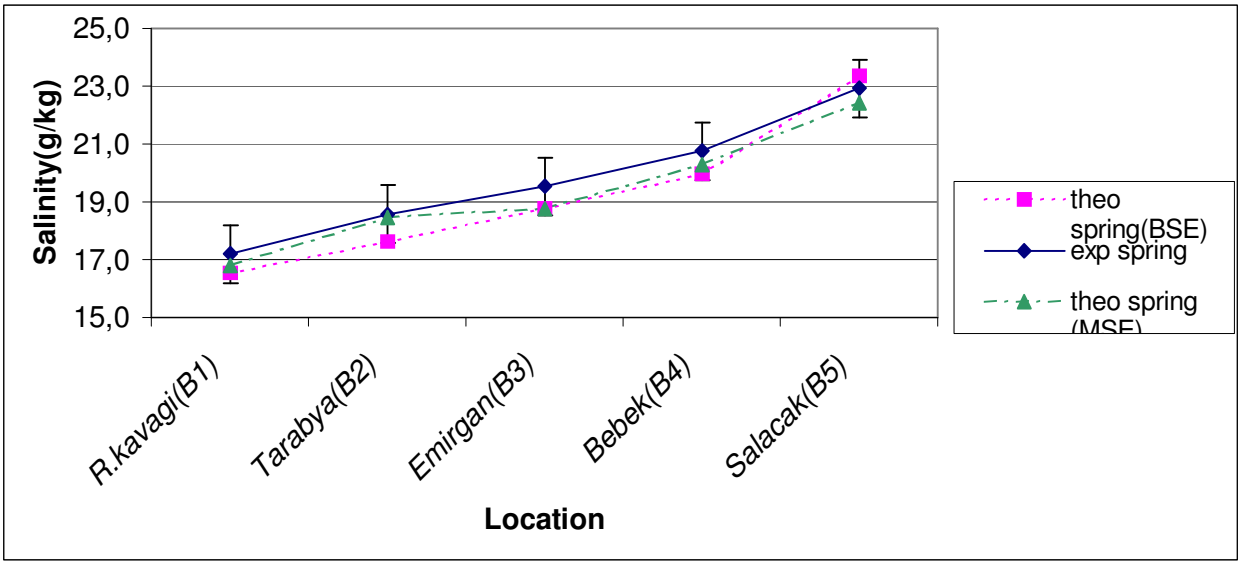


**Figure 2. Salinity dispersion in spring along Bosphorus with experimental and theoretical results**

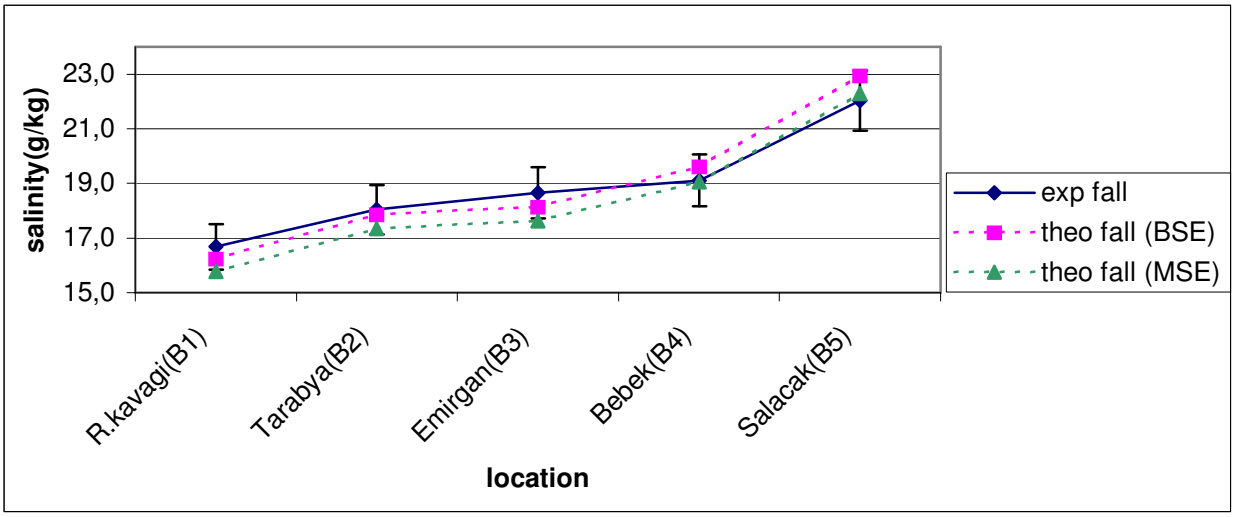


**Figure 3. Salinity dispersion in fall along Bosphoros with experimental and theoretical results**

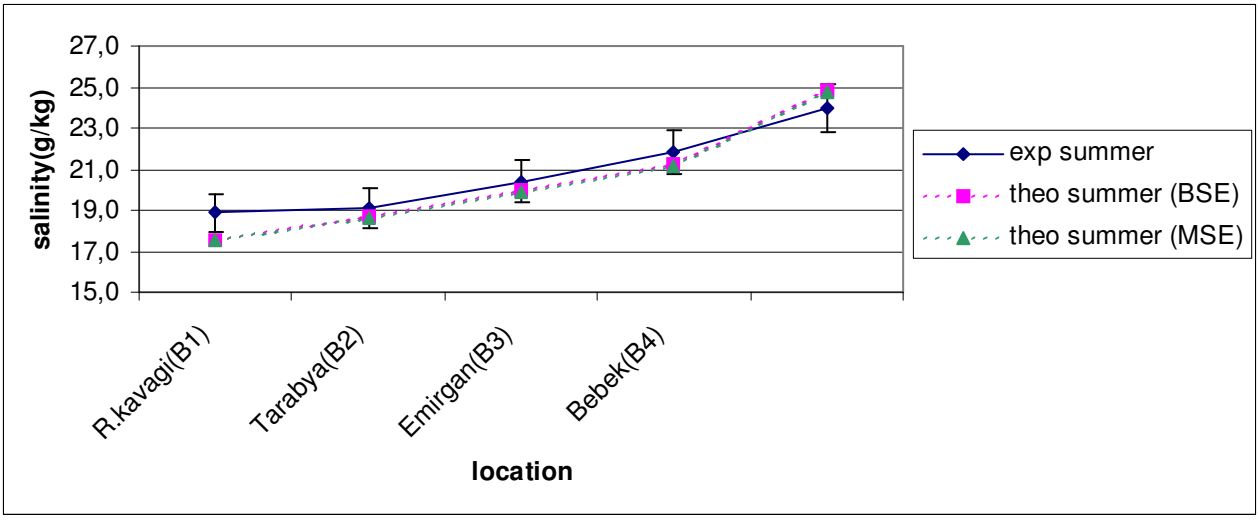


**Figure 4. Salinity dispersion in summer along Bosphorus with experimental and theoretical results**

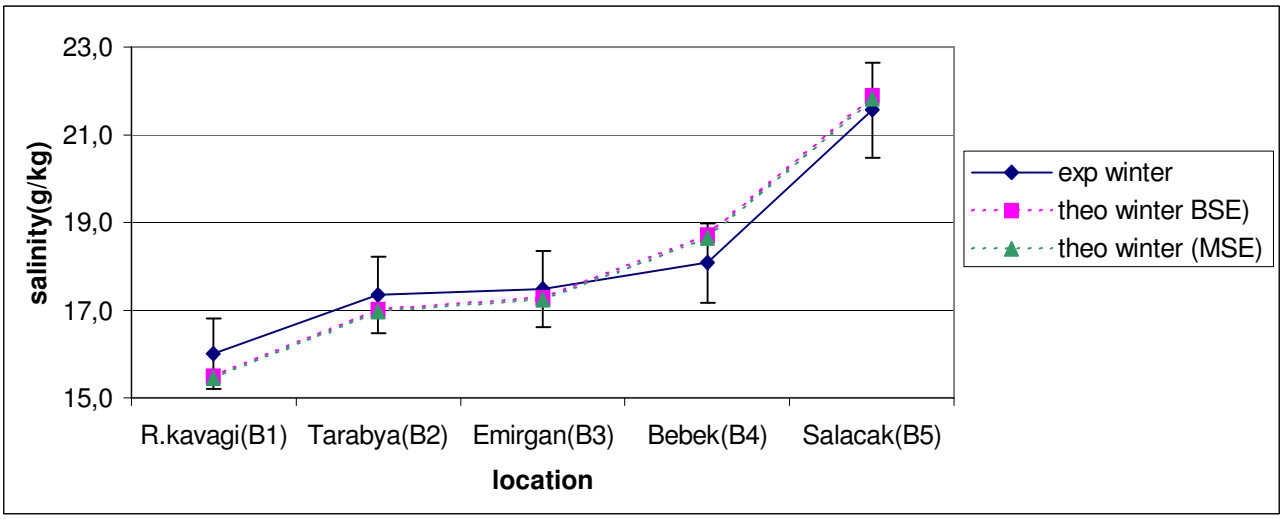


**Figure 5. Salinity dispersion in winter along Bosphorus with experimental and theoretical results**

## CONCLUSIONS

It is shown that;

- Neutron Activation Analysis is a convenient technique for salinity determination.
- Surface salinity is strictly directed to rainfall or in other words with the evaporation.
- As the rainfall increase in winter, the salinity gets lower. The decrease in rainfall causes less more evaporation thus more salinity. The salinity change deals with rainfall or evaporation very much.
- Surface salinity dispersion model of Bosphorus gives close results with the Neutron Activation Analysis experimental results.
- Salinity dispersion in Bosphorus is convenient with exponential function.
- The salinity dispersion equation developed for Bosphorus can be used in two forms;
    - ➢ If Black Sea (as BSE on the graphs) is chosen as the initial point of the salinity dispersion, then the exponential equation is positive. In other words, the initial point is selected as the lower salinity .($S = S_0 \exp(\beta x/L)$)
    - ➢ If Marmara Sea (as MSE on the graphs) is chosen as the initial point, the exponential equation is negative.($S = S_0 \exp(-\beta x/L)$)

- For example, the salinity results for MSE in summer (highest salinity, lowest rainfall) for B1, B2, B3, B4 and B5; 17.499, 18.632, 19.839, 21.124, 24.712, respectively and for BSE; 17.579, 18.718, 19.930, 21.221, 24.826, respectively.

- The percentage error of experimental results with MSE is 2.964% and the percentage error of experimental results with BSE is 3.078%. All the theoretical values are in the error approximation of the experimental results.

Briefly, it can be said that the experimental results taken using Neutron Activation Analysis suit with the equation of salinity dispersion along Bosphorus.

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