# NEW APPROACH TO SALINITY DETERMINATION & SALINITY DISPERSION ALONG BOSPHORUS

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## Abstract

Salinity is an important parameter for seawater in the different point of environment. For the environmental evaluation, salinity levels control the type of plants and animals that can live in different zones of the estuary. Three thermodynamic parameters are needed to derive the state of seawater. Salinity (S), temperature (T) and pressure (P). Neutron activation analysis (NAA) method is proposed to measure the salinity of seawater samples irradiated by Howitzer (a neutron source). This method is different from the other techniques because of using sodium concentration instead of chlorine. NAA is applied to determine the salinity of Sea of Marmara and Bosphorus samples also the seasonal salinity dispersion along Bosphorus is mentioned.

**Keywords:** Salinity, NAA, Sodiumchloride, Bosphorus

## 1. Introduction

It has been known that the composition of seawater is almost constant in space and time. Therefore, to a good approximation, oceanographers assume that seawater consists of just two components, pure water and all dissolved ions that contribute to the mass of seawater, namely salinity (Grasshoff *et al.*, [1]).

Salinity, a measure of the dissolved salts (sodium, potassium, magnesium, sulfur, calsium and chlorine) in seawater, is a fundamental property of seawater and basic to understanding biological and physical processes in coastal waters. Here, the most important compound among the salts is sodiumchloride whereas its sodium ($Na^+$) and chlorine ($Cl^-$) ions. 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*, [2]).

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.

Routine salinity measurement techniques are hydrometer, salinometer, evaporation and titration. Hydrometer measures the salinity with the specific gravity which is the ratio of the densities of two substances. Salinometer measures the electric conductivity and relates it with salinity of the sample. Refractometers are used to measure substances dissolved in water, using the principle of light refraction through liquids.

Evaporation method is a basic of salinity measurement methods. When water is evaporated, the salt remains as the residue. The ratio between the evaporated water and the residue is the salinity. However salt, being hygroscopic, retains water tenaciously in its crystal lattice as it is formed. To be sure that all water is evaporated infrared light source can be used after the residue remains. Using the water and salt relation, salinity can be determined. Pollution is another factor for the sensitivity of the natural salinity because there are salt compounds in the pollutants. Hence, sodiumchloride is a preferable measuring compound of natural salinity.

Titration is a chemical method. When Silver Nitrate ($AgNO_3$) is added to seawater sample, the nitrate ion ($NO_3^-$) becomes unreactive but the silver ion ($Ag^+$) is rapidly taken up by the chlorine ion ($Cl^-$). Every silver ion added is grabbed by a chloride ion. When the added silver ions are counted, the chloride ions are determined by a close association. From the chloride ions the salinity of the sample is determined.

All the salinity measurement techniques have problems, but physical techniques are generally preferable due to their simplicity.

New developing techniques are aimed to determine the salinity with high sensitivity and accuracy. Different new techniques are developing to cover the problems of other salinity measurement techniques. One of them is to detect the salinity from the satellite with remote control (Camps *et al.*, [3]; Front *et al.*, [4]). Another new technique is fiber microsensors which are developed to measure the salinity as well (Grunwald *et al.*, [5]). At this time, neutron activation analysis is proposed for the salinity measurement as an advanced and alternative nuclear technique.

## 2. Materials and Method

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, [6]).

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) for the measurement and also evaluation of it.

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

${}_{11}Na^{24}$ is a gamma active radioisotope with two gamma decays of 1368.6 keV and 2754.0 keV with radiation probability of 100% and 99.9% respectively (Gilmore *et al.*, [7]; Tugrul *et al.*, [8]). Sodium is also a suitable radioisotope for detection because of its gamma energies. Table1 illustrates the properties of sodium and chloride more clearly.

**Table 1. Properties of Sodium and Chlorine Elements (Tugrul *et al*, [8])**

| Element | Half-life | Energy (keV) | Abundance (%) | Production Modes | Thermal Neutron Cross-section (Barns) |
|---|---|---|---|---|---|
| Na-24 | 14.96 h | 1368.60<br>2754.00 | 100.00<br>99.94 | Na-23 (n,γ)<br>Mg-24 (n,p)<br>Al-27 (n, γ) | 0.513 |
| Cl-38 | 37.24 min | 1642.69 | 31.00 | Cl-37 (n, γ) | 0.423 |

## 3. 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, and B5) can be seen in Fig. 1.

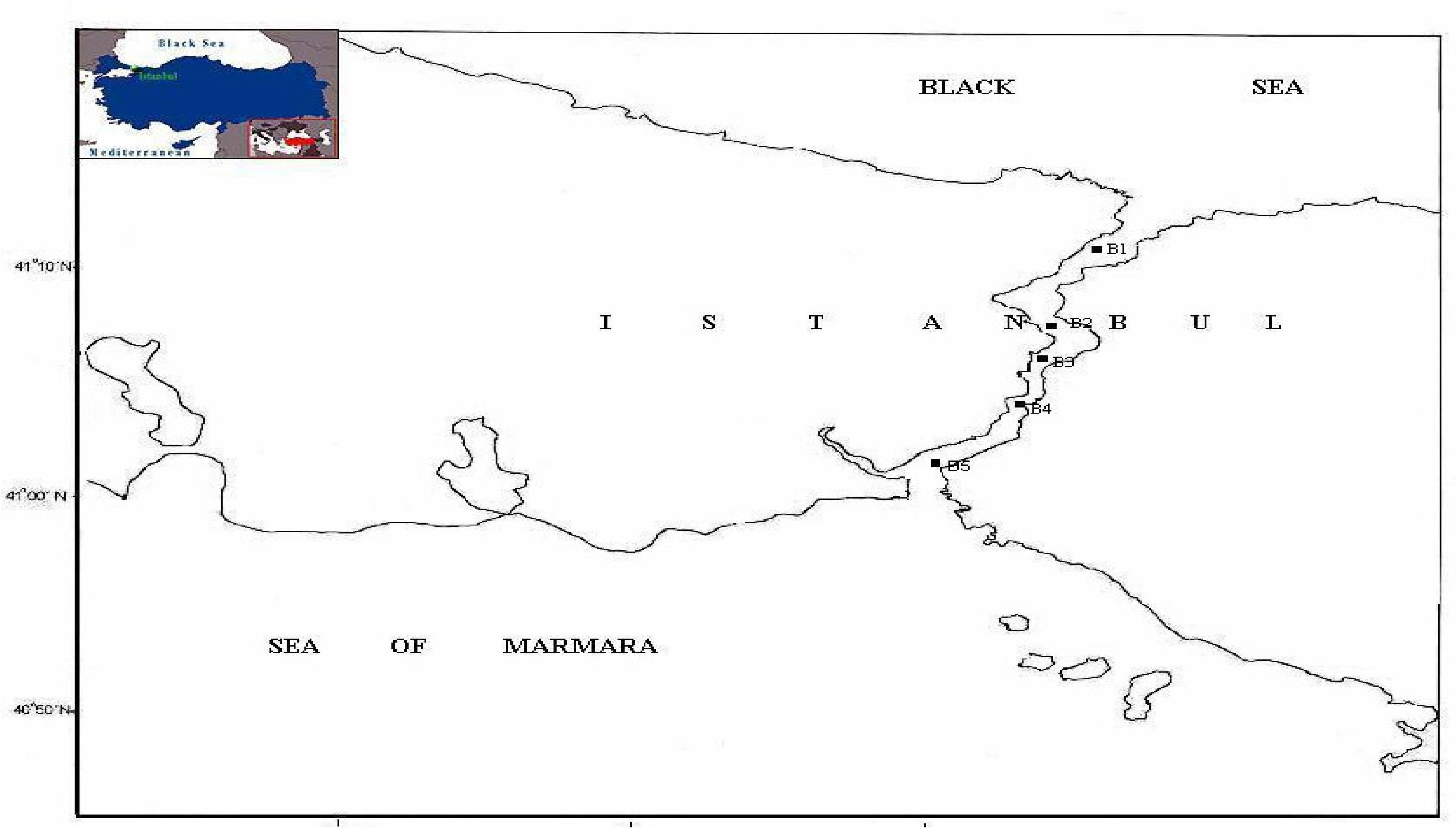



**Fig. 1. Sampling Location in Bosphorus**

A serial process was applied to the samples to be prepared for counting. All apparatus used in process was cleaned to prevent excessive radioactivity and contamination. Every seawater samples were transferred into different vessels which were weighted, and each of them was placed on hot plate to evaporate water without boiling, and evaporating process was continued under infrared lamp. After weighing vessels again, net weight of residues was determined. Then 100mg of residues were taken from the residues for the irradiation. In addition to them, 100mg of pure sodiumchloride reference sample were also prepared for the irradiation. 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 5cm thick lead cell with a NaI(Tl) scintillation detector. The results were taken from a multichannel analyzer with care. Using the Eqn (1), the salinity (S) of the samples is determined.

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

where, the sample factor ($\zeta$), which is the ratio of the net count for the irradiated sample ($N_s$) to mass of it ($m_s$);

$$\zeta = \frac{N_s}{m_s} \tag{2}$$

and reference factor ($\eta$), that is the ratio of the mass of the irradiated reference sample ($m_{re}$) to irradiated reference net count ($N_{re}$);

$$\eta = \frac{m_{re}}{N_{re}} \tag{3}$$

and residue factor ($\xi$), which is the ratio of the total sample residue mass ($m_{rs}$) to total evaporated water mass ($m_{ew}$)

$$\xi = \frac{m_{rs}}{m_{ew}} \tag{4}$$

Bosphorus is the channel where the Black Sea water ($S<17$) moves on the top and Mediterranean water underlies towards the Black Sea (Özsoy *et al*, [9]). These results were been taken by using conventional techniques and used by examine the NAA results. Mediterranean water is diluted thorough Bosphorus or Black Sea water gets more salty thorough it.

## 4. Results and Discussion

Counts were taken with care for many times. Salinities of the samples 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.*, [10]).

Surface salinity is strictly directed to rainfall or in other words with the evaporation. The average rainfall in Istanbul covering all the seasons is shown in Fig 2. As the rainfall increase in winter, the salinity gets lower. The decrease in rainfall causes more evaporation thus more salinity. The salinity change deals with rainfall or evaporation very much.

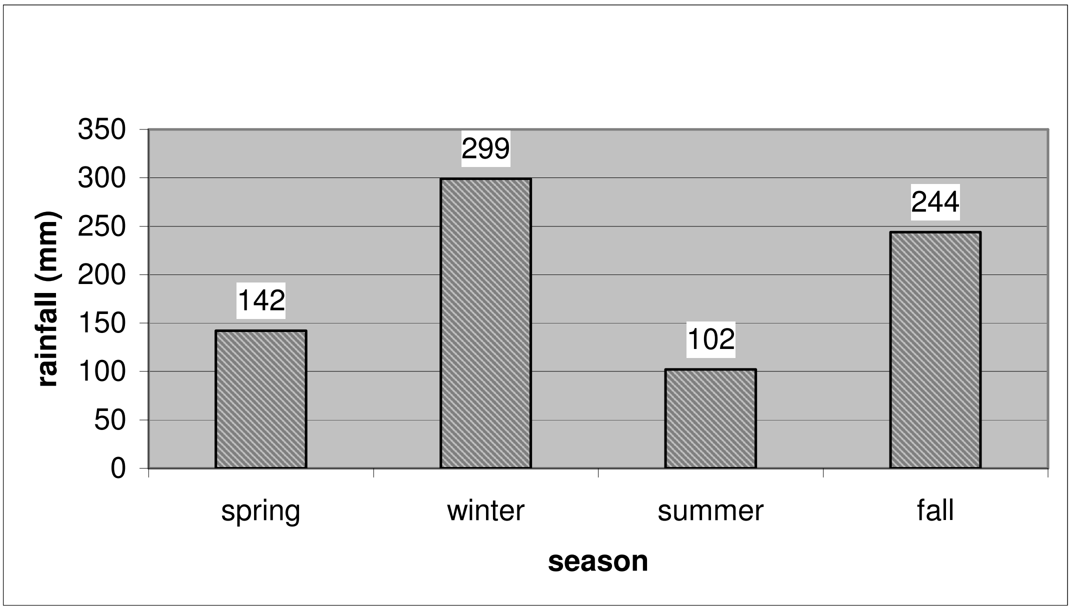



**Fig. 2. Seasonal rainfall average of Istanbul**

In Table 2, the comparison of salinity dispersion along Bosphorus is mentioned totally with reference experimental results covering two techniques which are NAA and evaporation.

**Table 2. Comparison of the Salinity Results with Different Measuring Methods for Bosphorous Samples of Surface**

| Sample location | season | Salinity(g $kg^{-1}$) with Evaporation | Salinity(g $kg^{-1}$) with NAA | Salinity(g $kg^{-1}$) literature values (Bayazıt, [10]) |
|---|---|---|---|---|
| B1 | Fall | 17.48±0.54 | 16.67±0.30 | ~17.00 |
| B2 | Fall | 18.24±0.66 | 18.04±0.33 | ~18.00 |
| B3 | Fall | 19.34±0.63 | 18.65±0.31 | ~18.00 |
| B4 | Fall | 19.91±0.61 | 19.11±0.29 | ~19.00 |
| B5 | Fall | 20.51±0.58 | 20.26±0.30 | ~20.00 |
| B1 | Winter | 17.19±0.59 | 16.01±0.27 | ~16.00 |
| B2 | Winter | 18.45±0.65 | 17.35±0.29 | ~17.00 |
| B3 | Winter | 18.09±0.64 | 17.48±0.26 | ~17.00 |
| B4 | Winter | 18.62±0.70 | 18.07±0.25 | ~18.00 |
| B5 | Winter | 20.17±0.65 | 19.19±0.25 | ~19.00 |
| B1 | Spring | 18.23±0.67 | 17.78±0.24 | ~17.00 |
| B2 | Spring | 19.39±0.70 | 18.92±0.26 | ~18.00 |
| B3 | Spring | 19.58±0.90 | 19.15±0.26 | ~19.00 |
| B4 | Spring | 20.75±0.86 | 20.12±0.23 | ~20.00 |
| B5 | Spring | 21.10±0.72 | 20.61±0.25 | ~20.00 |
| B1 | Summer | 19.18±0.70 | 18.86±0.78 | ~ 18.00 |
| B2 | Summer | 20.36±0.60 | 19.12±0.75 | ~ 18.00 |
| B3 | Summer | 20.74±0.69 | 20.40±0.77 | ~ 19.00 |
| B4 | Summer | 22.14±0.69 | 20.75±0.84 | ~ 19.00 |

Figures 3, 4, 5 and 6 illustrate the seasonal salinity change in Bosphorus (origin is the beginning point of the Bosphorus from the Black Sea). All of the results are shown in Fig7 in bar form covering more than a year period research on salinity dispersion. The salinity values are strictly in dependence with rainfall statistics. They are inversely proportional with each other.

Because of the high pollution, the residue of samples is much more than the NAA salinity results. So, it can be thought that the results of the evaporation method couldn't represent only the natural salinity, but pollution materials as well for high polluted regions.

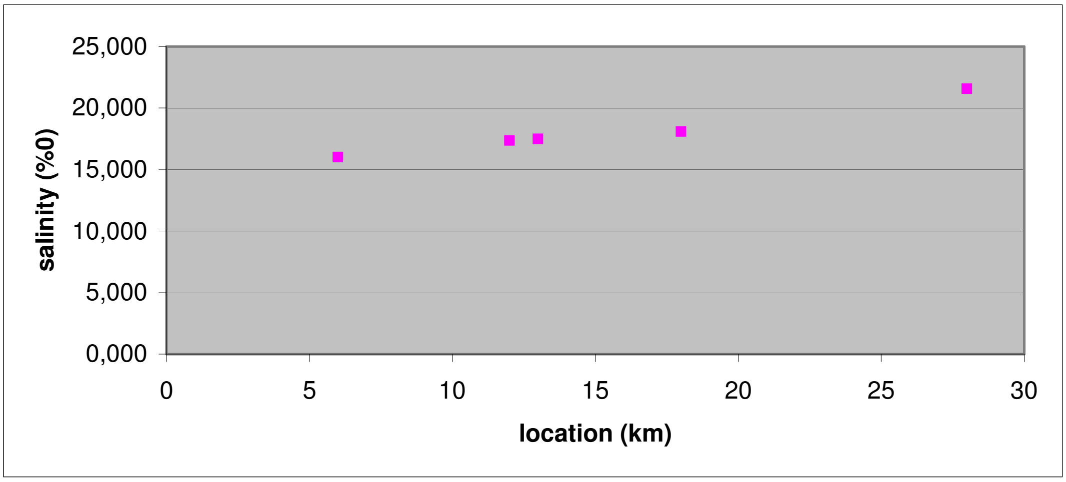



**Fig. 3. Experimental salinity dispersion in winter**

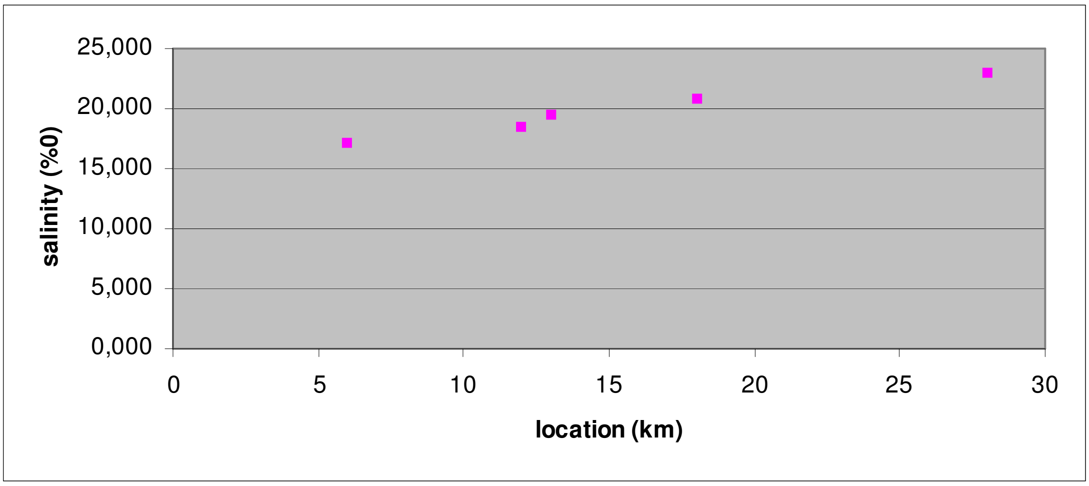



**Fig. 4. Experimental salinity dispersion in spring**

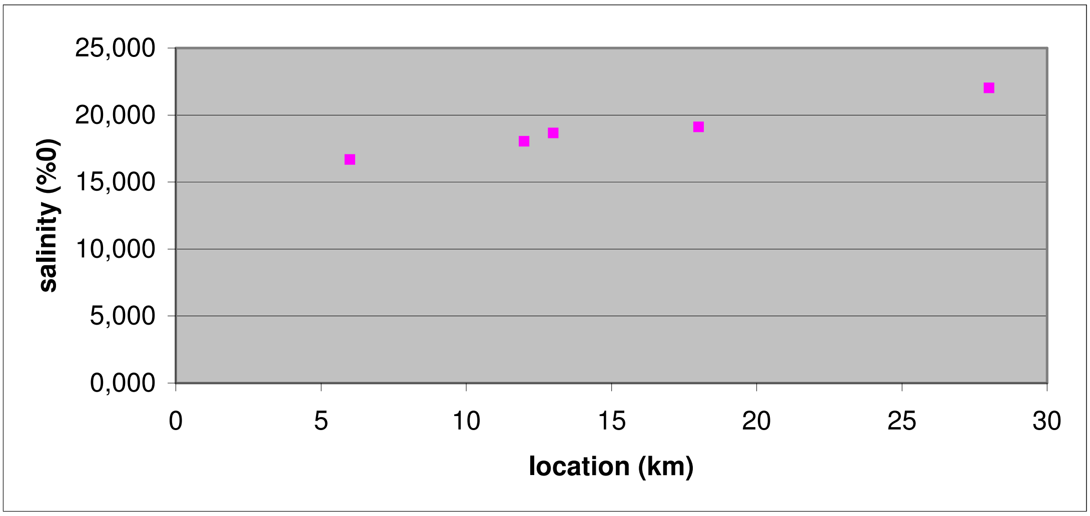



**Fig. 5. Experimental salinity dispersion in fall**

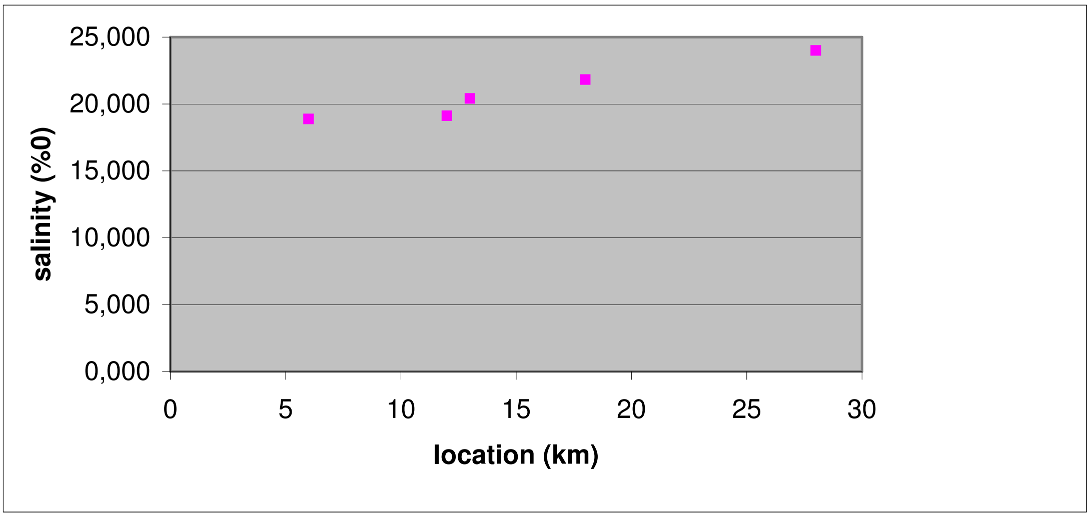
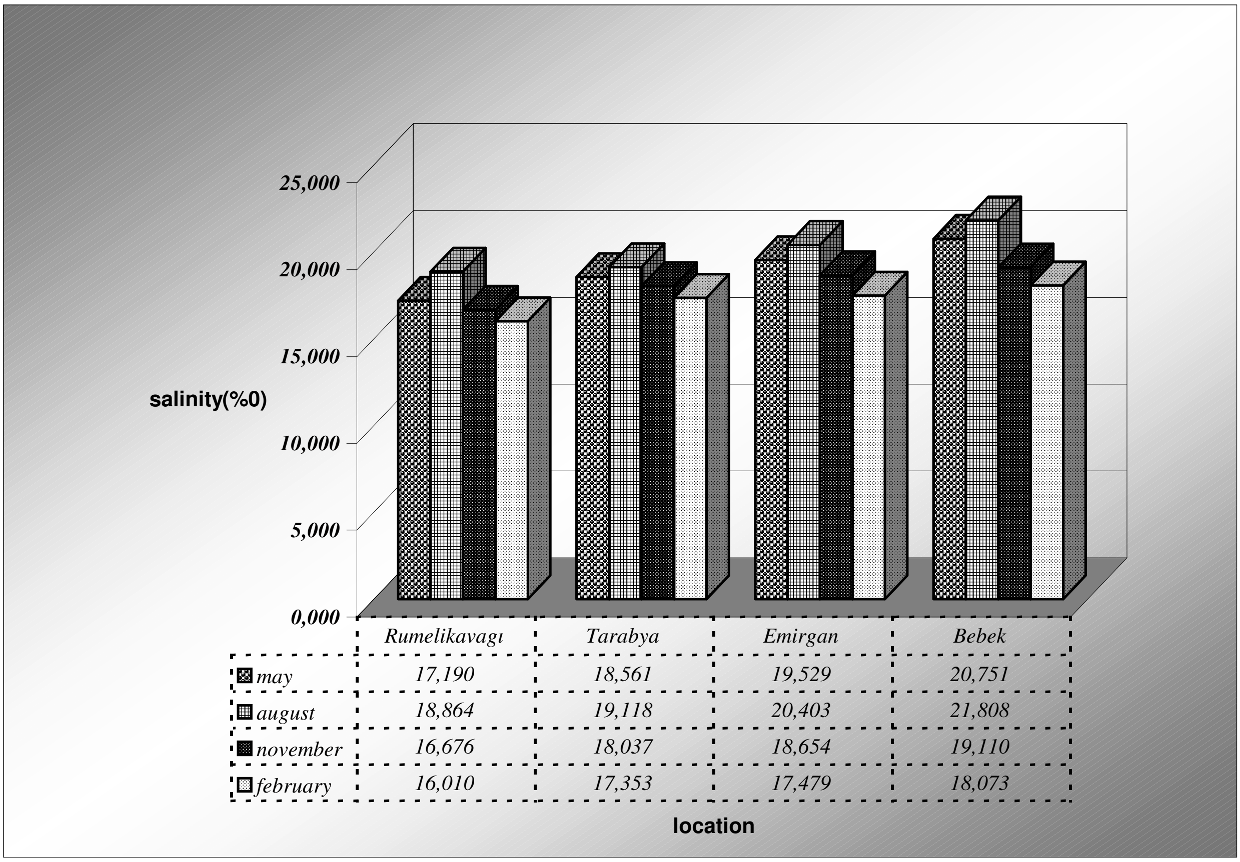



**Fig. 6. Experimental salinity dispersion in summer**




| | Rumelikavagı | Tarabya | Emirgan | Bebek |
|---|---|---|---|---|
| may | 17,190 | 18,561 | 19,529 | 20,751 |
| august | 18,864 | 19,118 | 20,403 | 21,808 |
| november | 16,676 | 18,037 | 18,654 | 19,110 |
| february | 16,010 | 17,353 | 17,479 | 18,073 |

**Fig. 7. Total review of the experimental results according to one year period**

## 5. Conclusion

Salinity is an important parameter for the environmental evaluation. Some species tolerate only intermediate salinity levels on the other hand some adapted species can live to any salinity ranging from fresh water to seawater. So, the natural salinity determination is important.

It is shown that;

- NAA is a convenient technique for salinity determination.
- NAA can be accepted as a reliable technique for salinity measurement due to results appropriation with another salinity measurement technique and with the literature data.
- All the salinity transition can be observed in success by using NAA.
- NAA gives the opportunity of detecting the salt compounds forming the salinity sensitively.
- As a different approach, the sodium concentration can be used for the salinity determination instead of chlorine concentration which can be taken basis in chemical techniques.
- For the polluted sea regions, it can be said that NAA is more sensitive and reliable (e.g. according to evaporation technique).

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