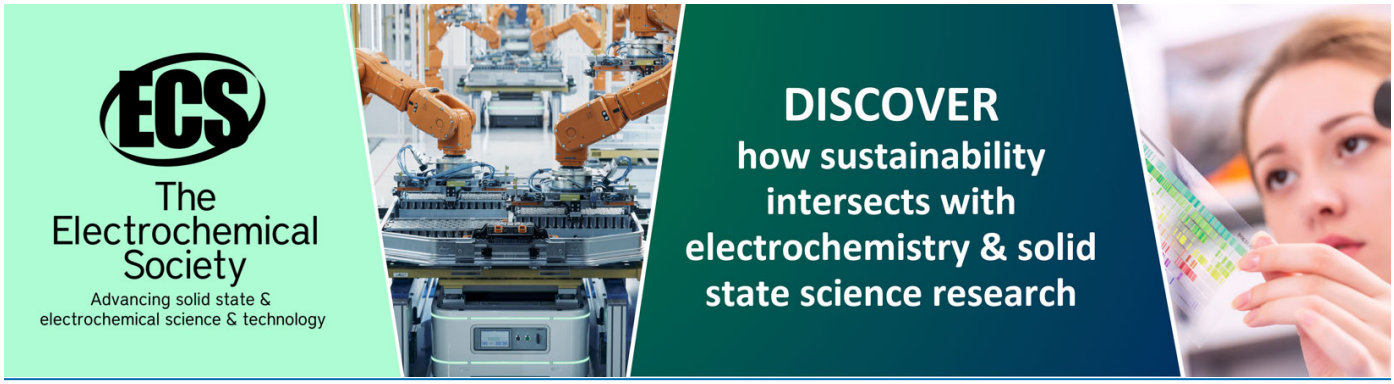
Cl/Br Ratio to Determine Groundwater Quality



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Abstract. Groundwater has different characteristics in each location influenced by mineral content in rocks that dissolves as water travels through the pores of rocks or soil or when stored in the soil (aquifer). Different minerals dissolving in rocks will lead to differences in anion content in groundwater. Chloride and bromide are the major ions that can be found in groundwater. The concentration of chloride is 500 times greater than the concentration of bromide. In addition, the high chloride concentration is a tracer for the influence of sea water. The ratio between chloride and bromide (Cl/Br ratio) can be used as a determinant of groundwater quality, as well as a determinant of groundwater contamination, sea water intrusion and the origin of sea water intrusion.

1. Introduction

Chloride and bromide are monovalent anions found in groundwater, as well as in potable water [1–3]. Chloride is a major ion and bromide is a minor one in water. Chloride is 40 to 8,000 times more than bromide in nature [1], and it is a halogen whose concentration in natural water is the most. The concentration of bromide in seawater in average is 65 mg/L [4]. Another research defined that the concentration of bromide in water is mostly < 1 mg/L [2,5], and the concentration of chloride in seawater is about 19.000 mg/L [6]. Chloride and bromide dissolve in water and they are ideal tracers because they behave conservatively when ionized in water, due to their hydrophilic character and small ionic size [1–3,5]. Sources of chloride and bromide are from atmospheric, evaporates, extrusion of brines, recrystallization of minerals, diffusion of ions, and sea water intrusion [3].

Groundwater quality is an important thing to determine, because it is commonly used as a source of clean water and irrigation [7,8], and in some areas it is used for agricultural and industry [9–11]. Several methods that can be used to determine groundwater quality are groundwater quality index [12,13], Geographic Information System or GIS [10,14,15], hydrochemistry analysis [7–9], and ion ratio [1–3,5,16–18]. One of the ion ratios is chloride bromide ratio (Cl/Br ratio).

2. Cl/Br ratio

Cl/Br Ratio can be applied in a lot of aspects. Some functions that correlate with groundwater are (a) as a tracer to determine the origin and evolution of groundwater and surface water [19], (b) an effective aid to hydrogeological studies in groundwater and surface water that have low to moderate concentration of salinity [1,20] (c) as a method to estimate aquifer recharge from precipitation using chloride mass balance like [2,5,20] (d) as a method to identify groundwater flow system that indicates the increase of salinity in the interaction between rock and water [21] (e) and also a method to identify source of groundwater like urban waste water, septic effluent, agricultural pollution, and leaching [1–3,5,16,18].

Analytical method to determine Cl/Br ratio is dividing the concentration of chloride by the concentration of bromide. There are two kinds of equation: using molar concentration (r), or weight concentration (p), expressed in this equation [1–3,5,16,18]:

$$\boldsymbol{R = \frac{rCl}{rBr} = 2.25\ \frac{pCl}{pBr}} \quad (1)$$

The result from the equation (R values) provides information about water quality, Interpretation of Cl/Br ratio or R values according to several researches [1–3,5] which are:

- Unpolluted marine water, R = 655 ± 4
- Recharge water, R = 400-500
- Continental rainwater, R = 50 – 650. In area where atmospheric air is seriously affected by the burning of automotive fuels, R is sometimes < 50
- Coastal rainwater, R is similar to or smaller than marine value
- Deposition derived from marine aerosol, R > 800
- Salinity from leachate or saline urban waste, R = 750 -1000
- Leachate from septic tank, R – 450
- Volcanic gas contributing halides, mostly R > 650, sometimes up to 900, although widely variability is observed

To observe the Cl/Br ratio, the result of the equation is commonly plotted by Cl/Br ratio versus chloride concentration. Examples of analysis Cl/Br ratio from several researches are in Figure 1 [5] and Figure 2 [3].

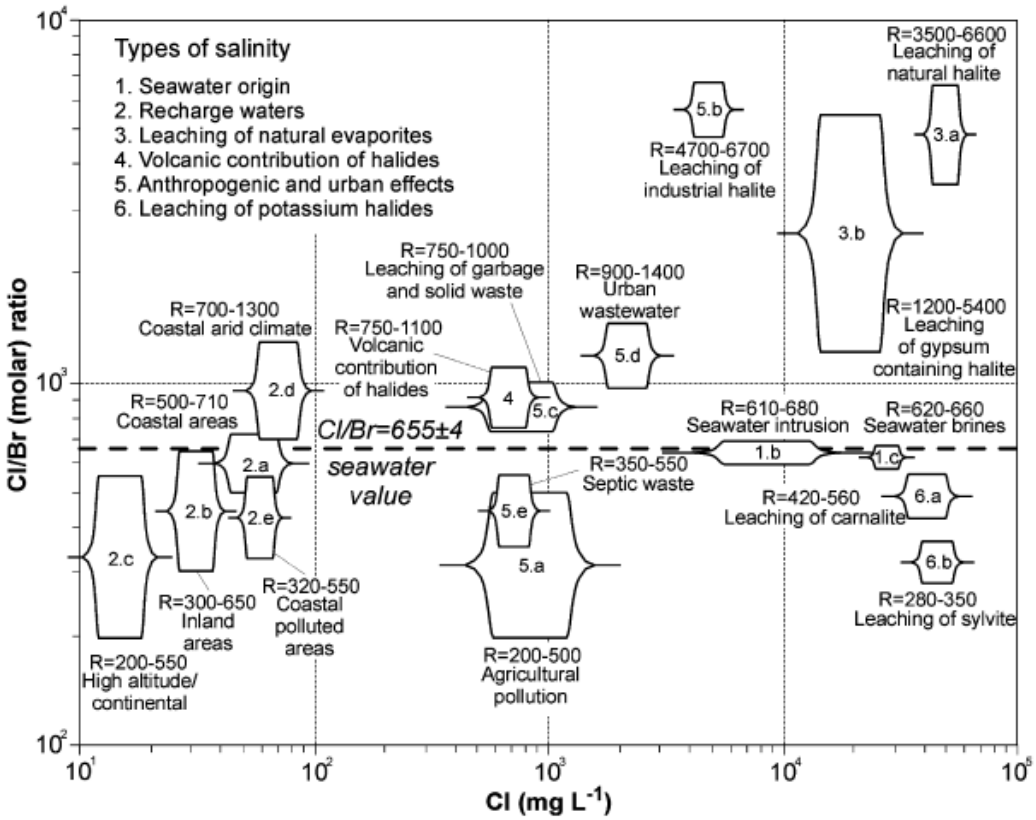

Figure 1. Plot of Cl/Br ratio versus chloride concentration for six types of salinity described in 24 selected aquifers of Spain and Portugal [2].

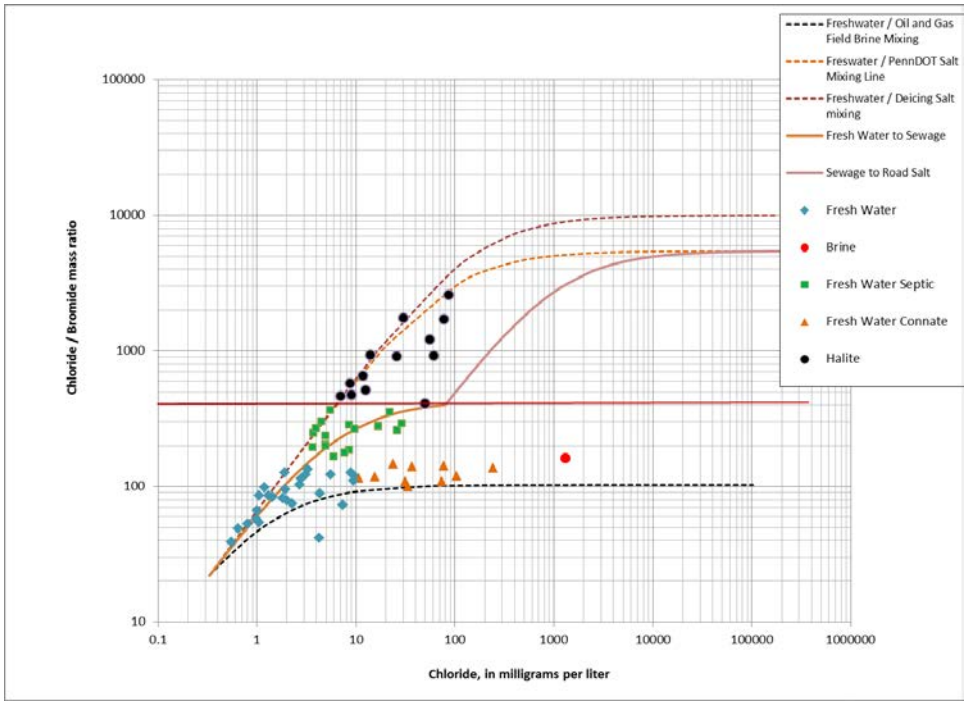

Figure 2. Plot of Cl/Br ratio versus chloride concentration used to determine 5 water types: fresh water, brine, fresh water septic, fresh water connate, and halite [3].

3. Conclusions

Cl/Br ratio can be used to determine groundwater quality; the method is calculated by an equation using molar concentration or weight concentration of chloride and bromide. Plotting of Cl/Br ratio versus chloride allows identification of possible sources of groundwater contaminant.

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