DETERMINATION OF RECHARGE AND EVOLUTIONARY STUDY IN NEW WELLS AT BERLIN GEOTHERMAL FIELD USING ISOTOPES

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ABSTRACT

Monitoring of isotopes from meteoric waters at different altitudes can help to establish the recharge area in geothermal fields, especially when there is not correlation between isotope composition from shallow waters and isotopes composition from geothermal wells. In this sense CEL have been made a preliminary study at Berlin geothermal field in order to estimate the recharge area. The results using data since 1996 to date shows an average altitude of 1350 masl this value is in agreement with hydrological and geological studies, which correspond to an infiltration zone located around the Berlin-Tecapa complex. Isotopic composition from Laguna de Alegría located in the same complex and Rio Lempa located 12 km away from the field shows that there is not relation with the recharge of the Berlin geothermal field. Also, an evolutionary study of the geothermal wells shows three definite groups: new wells, production wells and reinjection wells. Isotopic composition in recently drilled wells is changing with time, showing more depleted values ($\delta^{18}O$=-4.92°/$_{oo}$ to $\delta^{18}O$=-6.62°/$_{oo}$ and δD=-44.63°/$_{oo}$ to δD=-50.88°/$_{oo}$) than production wells in which isotopic composition is seated in the range $\delta^{18}O$=-3.5°/$_{oo}$ to $\delta^{18}O$=-3.9°/$_{oo}$ and δD=-42°/$_{oo}$ to δD=-45°/$_{oo}$. It suggest new wells still have a mixture of geothermal water and water introduced along the drilling. One exception is well TR-4B, it isotopic composition shift from $\delta^{18}O$= -5.67°/$_{oo}$ to $\delta^{18}O$=-3.78°/$_{oo}$ and from δD=-47.51°/$_{oo}$ to δD=-42.48°/$_{oo}$. Reinjection wells seems to have not impact over production wells, at least with the available information. Monitoring is still on.

INTRODUCTION

Berlin geothermal field is located approximately 100 km to east of San Salvador and it is associated with volcanic complex Berlin-Tecapa and Holocene Berlin caldera. The geothermal field has approximately 6 km ^{2} but according reservoir studies the field could be extended to 10 km^2. In 1977 CEL developed the first geoelectrical and gravimetric studies allowing to drill exploration wells. At the beginning of ninetieths CEL installed two wellhead units of 5 MWe of capacity each one and were drilled reinjection wells. At present Berlin field produces approximately 7 MWe but CEL is developing since 1996 an expansion project and is expected that at middle of 1999 is in operation a new power plant that will produce around 56 MWe. Reservoir studies estimate total capacity of the field in 100-150 MWe. Up to date, were drilled 16 new wells among reinjection and production wells and since then, an exhaustive monitoring of evolution of the field is carried out. Besides, several geochemical and isotopes studies were carry out by CEL to characterize the shallow and thermal waters. Additional to this information CEL started in 1996 a complete isotope study of precipitation with the support of the International Atomic Energy Agency in order to estimate the recharge of geothermal field. In this way CEL installed 3 collectors of rainwater at different altitudes near to the geothermal field.

WATER CHEMISTRY

Several samples were taken near of the geothermal field. Springs, domestic wells and thermal waters have temperatures between 37°C to 98°C and pH between 6.3 to 8, the chloride content of those samples are between 2 to 1142 ppm. The well discharge waters have chloride between 4700 to 9500 ppm. The figure 1 present the relative content of $Cl:SO_4:HCO_3$ (Giggenbach, 1986). In this figure we can observe that most of the samples are HCO_3 type (surface waters) and only few samples (F-126, F-128, F-129, F-20, F-144B, F-145, F-146), are chloride type and one sample (F-144) is SO_4 type. Those samples located to the northwest of the geothermal field do not have relation with Berlin geothermal system from the isotope point of view (A.Matus, 1996 and M.Magaña, 1998).

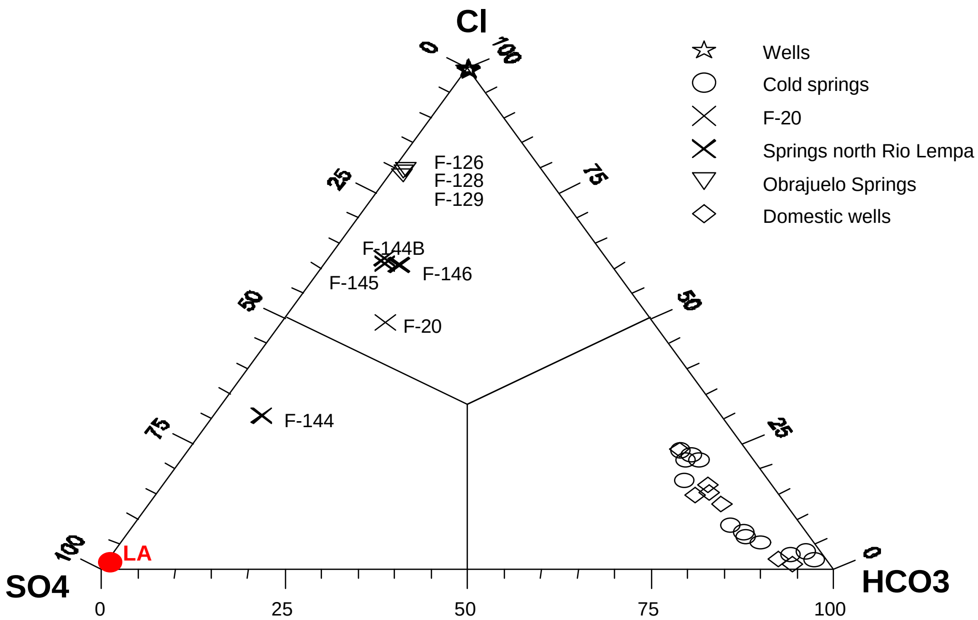


Figure 1. Cl-HCO3-SO4 triangular diagram for Berlin Geothermal system

ISOTOPE COMPOSITIONS

Isotopes of rainfall

The laboratory of stable isotopes collected monthly since 1996 rainfall samples. Collectors were placed at different elevations (220, 690 and 1594 m.a.s.l.). These collectors are commercial containers of water (plastic containers), the capacity is around 20 lt. and they have a protection against the sun (wood or compressed polystyrene) and have 1iter of paraffin to avoid the evaporation of the sample. Samples isotope compositions were measured in the Laboratory of Stable Isotopes of CEL. The figure 2 present the Local Meteoric Water Line (LMWL) obtained for rainy season (all samples collected in summer season shows intensive evaporation and are not considered in the correlation) and the equation is: $\delta^2H = 7.92 \delta^{18}O + 9.51$ (Ec. 1) with a correlation of 0.992.

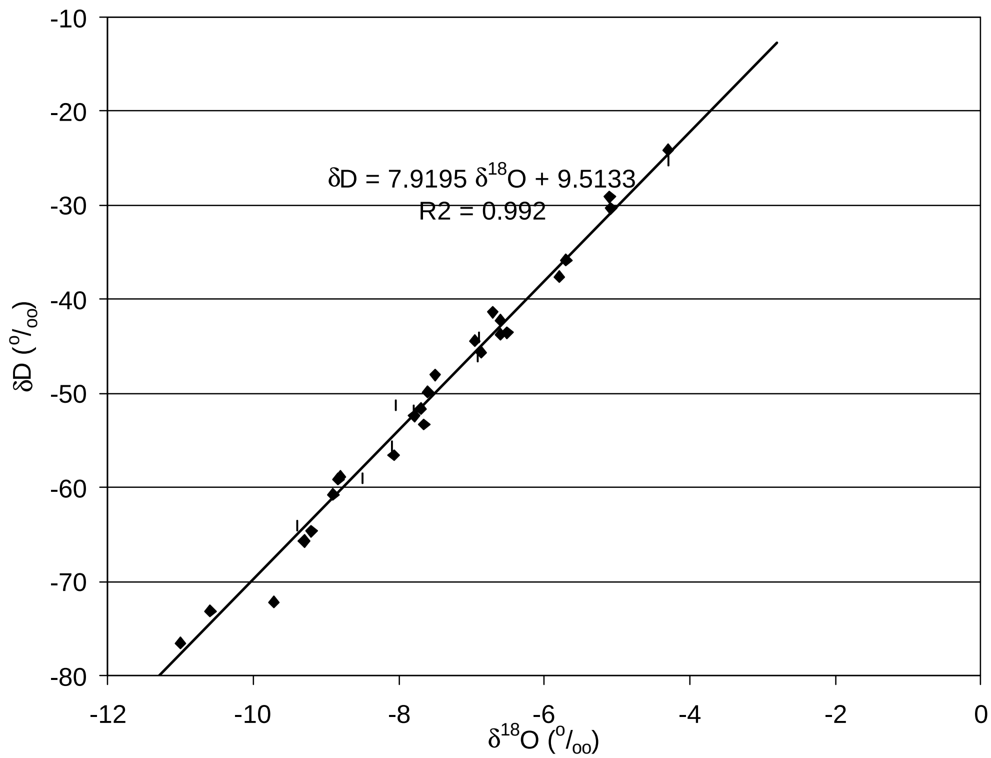


Figure 2. Local Meteoric Water Line for Berlin Geothermal system

The figures 3 and 4 show the variation between altitude and $\delta^{18}O$ and $\delta^{2}H$ for rainy season. The relations are:

$h = \frac{(-\delta^{18}O - 6.4)}{0.0026}$ (Ec. 2) with a correlation of 0.9871 and

$h = \frac{(-\delta^{2}H - 42.3)}{0.019}$ (Ec. 3) with a correlation of 0.991.

It means that isotopic composition decreases 0.26 in oxygen and $1.9^{0}/_{00}$ in deuterium for every 100 m increase in altitude.

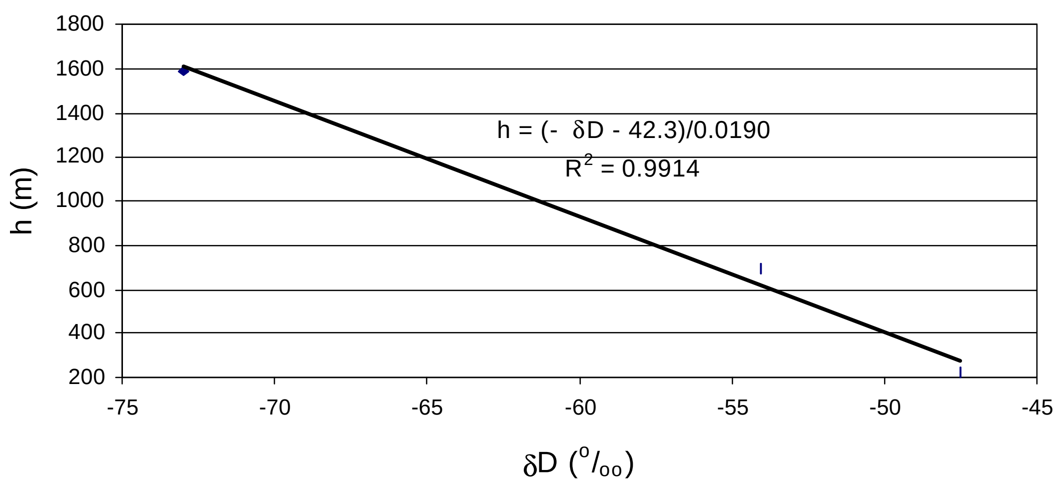


Figure 3. Relationship between Altitude and $\delta^{18}O$ for Berlin Geothermal System

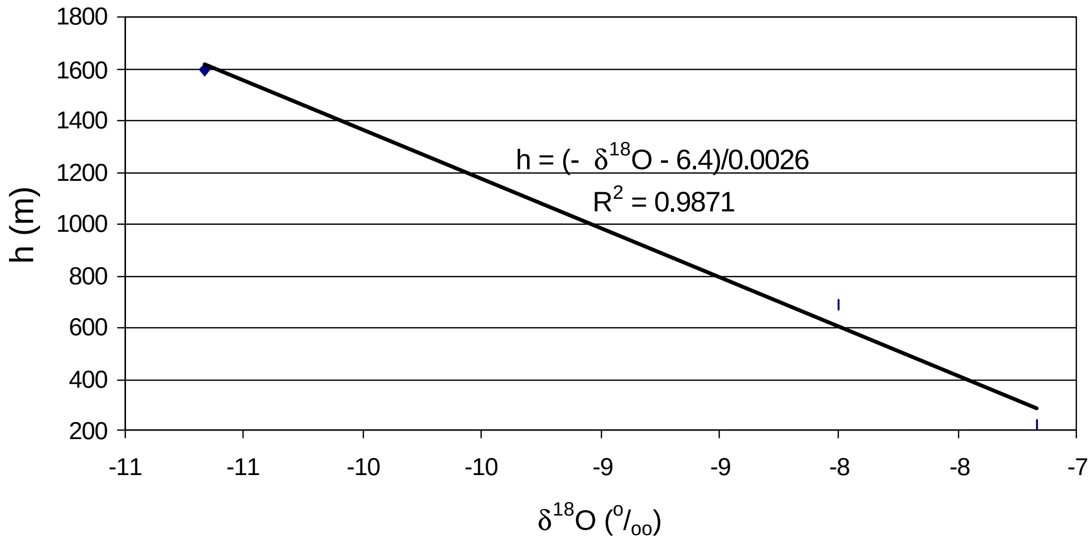


Figure 4. Relationship between Altitude and δD for Berlin Geothermal System

Isotopes of production and reinjection wells

Several samples from geothermal wells were collected since 1991 the isotope values were obtained in Laboratories of Italy, Vienna and CEL. The values in total discharge are between -3.4 to -4.66 $^{0}/_{00}$ in oxygen and -31.7 to -49.96 $^{0}/_{00}$ in deuterium. The reinjection waters are between -2.2 to -2.9 $^{0}/_{00}$ in oxygen and -38.7 to -44.35 $^{0}/_{00}$.

DETERMINATION OF THE RECHARGE

The figure 5 present isotopes of deep geothermal waters, shallow cold waters, thermal waters and reinjection wells. We can see in this graphic isotope composition of Laguna de Alegría (LA) with -1.42 $^{0}/_{00}$ in oxygen and -12.2 $^{0}/_{00}$ in deuterium, located to the south-southeast from the geothermal field and the Río Lempa (RL) with -4.76 $^{0}/_{00}$ in oxygen and -33.62 $^{0}/_{00}$ in deuterium, located to the west of the geothermal field. Both present different grade of evaporation. Those places are isotopic distinct and suggesting a different source of recharge from the well waters. Additional to this we can see the line of isotopic of samples F-128, F-126, F-129, F-144, F-144B, F-20, F-145 and F-146, do not have relation with the geothermal wells, so the discharge of the Berlin geothermal field is still unknown. The regression for geothermal wells give the follow value: $\delta^2H = 3.81\ \delta^{18}O - 31.08$ (Ec. 4). If we combined the equations (1) to (4), we get in average a recharge altitude of 1350 m.a.s.l, this value is agree with hydrologic and geologic studies (H. Correia, et. al, 1996). At the moment there are not changes in isotopic compositions due to the effect of reinjection into the wells located at the north of the production field. In the other hand, using chemical and production data and also from tracers experiments the influence of the reinjection is not observed.

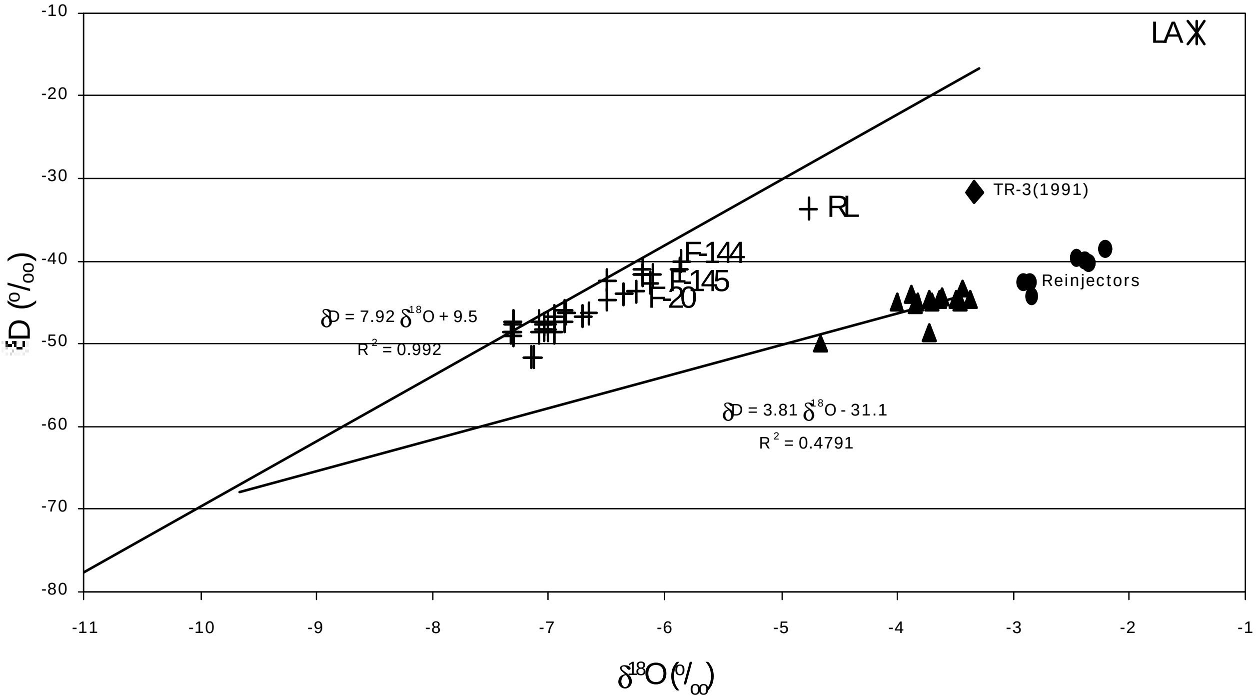


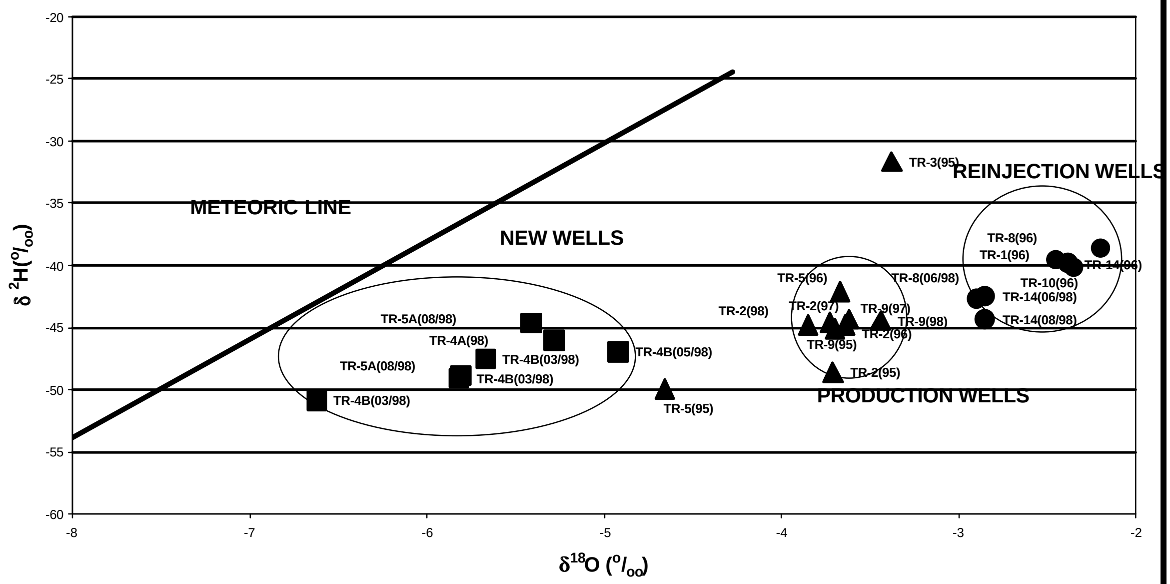
Figure 5. Isotopic composition for geothermal wells and some shallow water in Berlin Geothermal System

EVOLUTION STUDY IN NEW WELLS

CEL is developing since 1996 an expansion project of the Berlin Geothermal Field. Is expected that at middle of 1999 is in operation a new power plant that will produce around 56 MWe. Reservoir studies estimate total capacity of the field in 100-150 MWe.

Up to date, were drilled 16 new wells among reinjection and production wells and since then, an exhaustive monitoring of evolution of the field is carried out. Table 2 in appendix shows isotopic composition and chloride contents in total discharge for all the wells since 1995 to 1999. Those values are represented graphically in the Figure 6 and Figure 7. Because reinjection water is present in the absorption zone of each reinjection well, same chloride content in liquid and in the liquid reservoir is assumed.

Figure 6. Isotopic Composition in geothermal wells at Berlin Geothermal Field
$\delta^{18}O$ vrs. $\delta^{2}H$



Both in figure 6 as in Figure 7 are 3 defined zones: new wells, production wells and reinjection wells. New wells have more depleted values ($\delta^{18}O$=-4.92 $^{o}/_{oo}$ to $\delta^{18}O$=-6.62 $^{o}/_{oo}$ and δD=-44.63 $^{o}/_{oo}$ to δD=-50.88 $^{o}/_{oo}$) than production wells in which isotopic composition is seated in the range $\delta^{18}O$=-3.62 $^{o}/_{oo}$ to $\delta^{18}O$=-3.85 $^{o}/_{oo}$ and δD=-44.33 $^{o}/_{oo}$ to δD=-48.62 $^{o}/_{oo}$.

Sample of well TR-5 from 1995 is an anomalous value both in isotopes as in chloride content. Probably because the well was closed for a long time and the sample was taken starting the discharge test.

Regarding to well TR-3 its isotopic value shows that this well is under a boiling process, which is in agreement with geochemistry data.

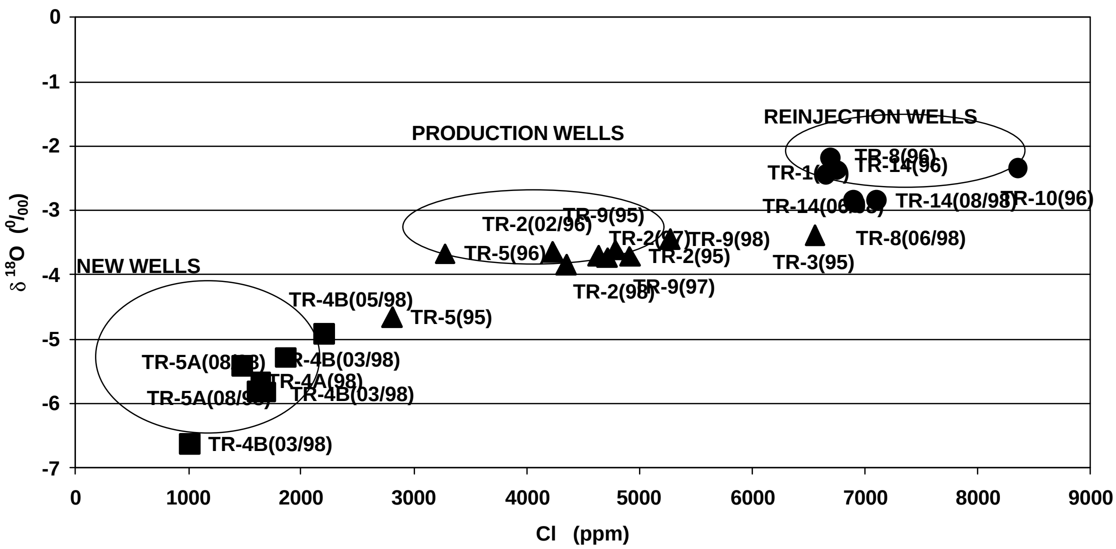
Reinjection wells isotopic data are more enriched in weight isotopes due flashing process. The range of isotopic composition in reinjection wells is $\delta^{18}O$=-2.2 $^{o}/_{oo}$ to $\delta^{18}O$=-2.85 $^{o}/_{oo}$ and δD=-38.7 $^{o}/_{oo}$ to δD=-44.35 $^{o}/_{oo}$

Is important to note in Figures 6 and 7 how the isotopic composition in new wells is changing with time and going to typical values of production wells.

Well TR-4B shows clearly this trend. It isotopic composition is shifting from $\delta^{18}O$=-4.92 $^{o}/_{oo}$ to $\delta^{18}O$=-6.62 $^{o}/_{oo}$ and δD=-44.63 $^{o}/_{oo}$ to δD=-50.88 $^{o}/_{oo}$ in less than one year. Sample of January of 1999 is close of the production wells area. Well TR-4C is shifting slowly due to a poor time of discharge. Well TR-4A was drilled as a production well but, at the moment is being used as reinjection well.

Figure 7. Relationship between Chloride content and Oxygen-18 in geothermal wells at Berlin Geothermal Field

Cl vrs. $\delta^{18}O$



Most new wells data are closer to meteoric water line and far from production wells data in more than values of international permitted accuracies (1.0 $^{o}/_{oo}$ for deuterium and 0.1 $^{o}/_{oo}$ for oxygen-18). It suggests that new wells still have a mixture of reservoir water and shallow water that was introduced along the drilling. This argument is valid for chloride contents too.

Is necessary to make an isotopic and chemical evaluation through new discharges of the wells, allowing the input of fluids with more water-rock interaction features.

CONCLUSIONS

The average altitude of the recharge of Berlin geothermal field is about 1350 masl. The hydrological studies pointed that the major infiltration zone is close to the Berlin-Tecapa complex located at the same altitude. (H. Correia, et. al, 1996)

The isotopic composition of shallow thermal waters F-128, F-126, F-129, F-144, F-144B, F-20, F-145 and F-146, presents different line of mixing respect than the deep geothermal wells reflecting a lack of relation between them.

No effect of the reinjection has been observed using isotopic results. This observation is supported also for the results of chemical, radiotracers and production data.

According to both isotopic and chemical information, is possible to say that new wells still have shallow water due to drilling.

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