Article

Health assessment of pine forest as affected by geothermal activities: Presence of Monterey pine aphid, *Essigella californica* (Essig) (Homoptera: Aphidae) associated with higher concentrations of boron on pine needles

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Abstract

Studies on assessments of the air pollution and deposition caused by geothermal fields on the forest health and presence of pests have been few documented to date. In the geothermal field “Los Humeros”, located between the borders of the states of Puebla and Veracruz, Mexico was realized a forest health monitoring to know the assessment could have these emissions of sulphur (S) and other two chemical elements measured by their concentrations on leaf tissues in the surrounding forests. For it were evaluated the forest healthy and pest insects registered at 20 stands of which were chosen completely at random 40 trees in total/site of the species *Pinus montezumae* and *P. teocote*in natural stands and plantations and picked up leaf tissue samples representatives per stand to determine the contents of sulphur (S), boron (B) and arsenic (As) representing each forest stand. The results of the study revealed that the presence of forest pests are not related to the proximity of the sites to emissions from stationary sources of emissions and moreover the amount of these 3 chemical substances monitored do not have none influence on the forest healthy sites condition, except for the Monterey pine aphid *Essigella califórnica* Essig, which seems to be directly associated with higher Boron content in the needles (mean=167.47± 32.15, and peak 635.46 ppm) and proximity of emission sources geothermal vents or where it is believed all these chemical elements are carried down by air currents to specific points and deposited in the stands. The general model obtained and with significance of R^2=56.6 and P value 0.0033 for the presence of Monterey Pine aphid and the three main pollutants released from smoke plumes in geothermal systems is [D: Essigella]= -0.2088 + 1.880E-0.5 (A:SO4)+ 0.002245 (B:B) + 1.248 (C:As). The results suggest the use of aphid species as bioindicators of polluted sites.

Keywords forest health monitoring; Monterey pine aphid; sulphur; boron; pollution; geothermal field; acid rain.

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1 Introduction

Geothermal activities represent open-loop systems emit hydrogen sulfide, carbon dioxide, ammonia, methane, and boron. Hydrogen sulfide and this last is the most common emission and has been the substance more studied by its cumulative effects on vegetation.

Once in the atmosphere, Hydrogen sulfide changes into sulphur dioxide (SO_2). This contributes to the formation of small acidic particulates that can be absorbed by the bloodstream and cause heart and lung disease (National Research Council, 2010). Sulphur dioxide also causes acid rain, which damages crops, forests, and soils, and acidifies lakes and streams (Agrawal et al., 1999; Priyanka et al., 2012). However, SO_2 emissions from geothermal plants are approximately 30 times lower per megawatt-hour than from coal plants, which is the nation's largest SO_2 source.

Geothermal plants also produce small amounts of mercury (Hg) emissions, vanadium (V), silica (SiO_2) compounds, chlorides (Cl-), arsenic(As), nickel (Ni), and other heavy metals (Kagel, 2007, 2008).

In soil science and plant physiology it is accepted that the amount absorbed of macro and micronutrients by the vegetables are in a direct function of the quantities in which they are available and similar to the ground, by natural mineralization processes, while another part, therefore, is fixed directly through to atmospheric deposition processes (Prajapati, 2012; Meravi and Prajapati, 2013). Indeed, major problems occur when comparing the nutrient content in the leaf tissue through space and time: Nutrient concentrations of foliage of conifers varies depending on the soil content nutrients (Bell and Ward, 1984) and the Woodland age and foliage (Florence and Chong, 1974; Mälkönen, 1974; Miller et al., 1981; Madgwick et al., 1983; Santerre et al., 1990), with the position of the needles in the twigs (Mead and Will, 1976) and annual physiological cycle (Kazda and Weilgony, 1988; Helmisaari, 1990). Consequently it is very difficult to adequately control the inherent variation foliar during sampling. Additionally, the exact nature of this variation has been identified for some species and nutrient dynamics of many tree species is still unknown. Various nutrients, including Potassium(K), Nitrogen(N), Phosphorus(P), Boron(B) and Magnesium(Mg), are very mobile and can therefore be prone to wide variation in function of time.

Accumulation of deposit substances in forests into processing annual deposition of NOx, chlorides (Cl-) and sulphur (S), solubility of heavy toxic metals due to air pollution on the soil surface—contributing to its constant acidification- and further transport through the soil profile into seepage and ground water down and directly under the tree crowns and their effects on forest health is evident (Van Breemen et al., 1988; Brechtel, 1989; Vrbek et al., 2006; Janik et al., 2012; Raju et al., 2013).

The main object of this research made in summer of 2010 was to understand the possible relationship between air pollutants concentration and forest health condition associated to the presence of Monterey pine aphid, *Essigella californica* (Essig).

2 Methodology

Forest health monitoring was organized with the aim of measuring the current state forest resource conditions and was performed according to the geographical location of the 20 sampling sites or stands and in each of them proceeded to make a quadrant radiating from the center and following the cardinal points (north (N), east (E), south (S) and west (W)) by drawing equidistant from the center line of 25 meters, according to Innes (1993). The standard method of plot assessment is lo locate four sub-plots on each plot and then to where at each end (edge) were chosen for evaluation and count 10 trees in visual point immediately surrounding per each ones of 4 edges per site, so that all the sites were diagnosed a total of 800 trees, which recorded the tree species, their plant condition according to 6 categories of vigor described by Vorontzov et al. (1991; Fig. 2) and Del Rio and Petrovitch (2011) as method for measuring the stress condition, presence or absence of pests or diseases, according trees crown visuals changes scales regarding generally grades of trees colonization attacked by bark beetles and other agents mostly, but is very useful when focused measuring the environmental stress on canopy and this relation is named semiology.

Fig. 1 View of a smoke plumes in geothermal system “Los Humeros”.

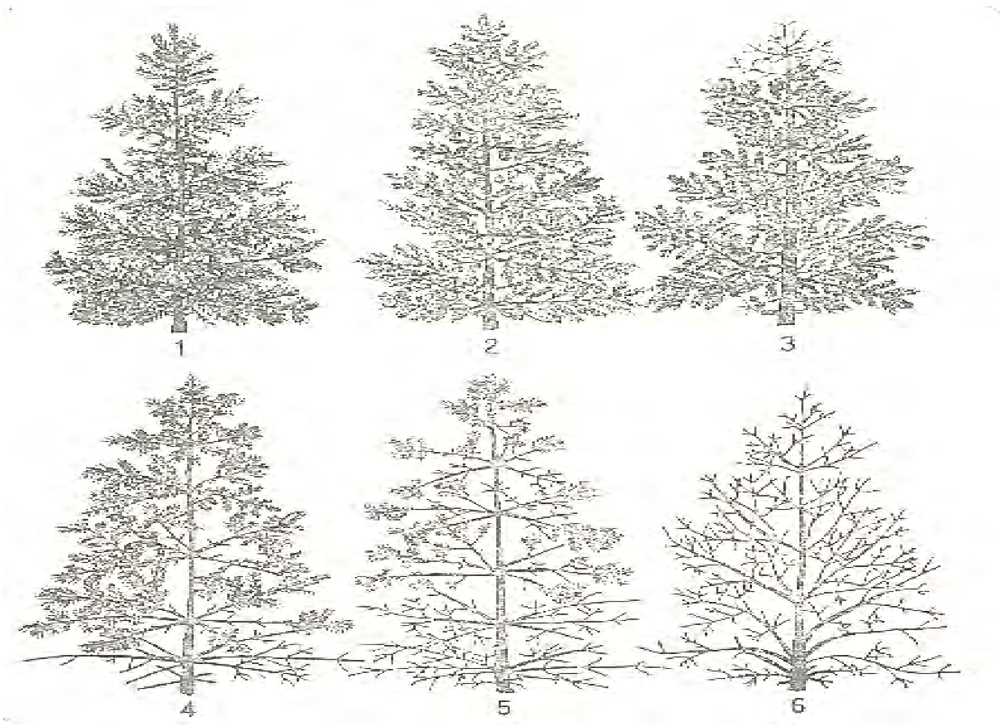

Fig. 2 Visual representation of 6 vigor categories in pine plantations (Vorontzov et al., 1991).

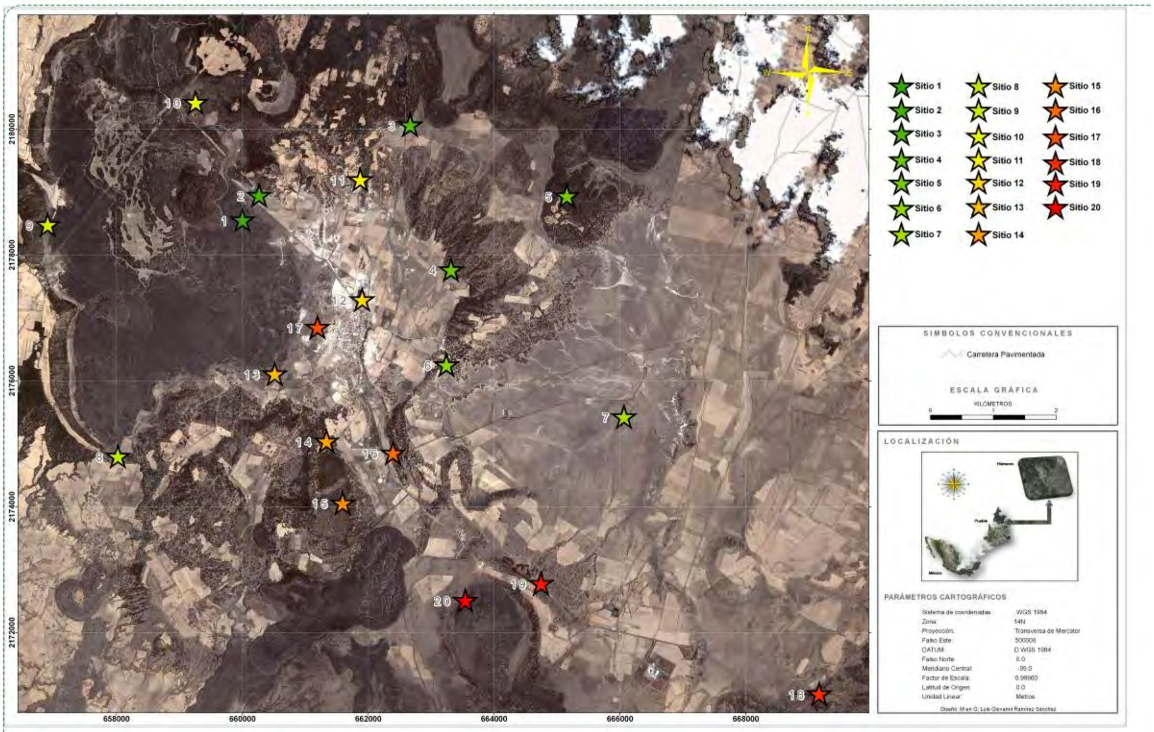

Fig. 3 Geographical distribution of the 20 stands monitored surrounding the geothermal zone: “Los Humeros”, Puebla, Mexico (Source: CFE, México 2010).

The area was considered for this study as Geothermal Field “Los Humeros”. It covers an area of 15,600 hectares in this area and is directly across the infrastructure including geothermal field (Fig. 1). They are located in the eastern part of the state of Puebla, Mexico, between parallels 19º37’03’’ and 19º43’32’’ north latitude and between the meridians 97º22’39’’ and 97º30’07’’ west longitude (Fig. 3). Forest healthy monitoring and samples of leaf tissue were performed in summer of 2011 and the selection of sampling sites was based on regionalization in homogeneous units, in each of which using a stratified random sampling (Darwich, 2003) (Fig. 1), were located 20 sampling sites (Fig. 8) focused for knowing the forest healthy conditions so far, besides picked up for each site samples of leaf tissue to determine the contents of sulphur (S), boron (B) and arsenic (As) representing each forest stand studied.

Samples mixed and homogenized of leaf tissue of 200 grs representatives for each one 20 sites were collected depending of existing woody vegetation sampling sites on the middle crown and second year growing allocated and according on tree species composition and representativeness or dominance, mostly *Pinus teocote*, *Pinus pseudostrobus* and *Pinus montezumae*. Samples were collected from the middle layer of foliage, different corners of the tree and old leaves (neither old nor too young) and considering the case of the development pines averaging less than two years, because according phenological estimates in this period includes the drivers vessel occlusion of needles, their drying and fall, process named “*natural* needle abscission*”* (Everett and Thran, 1992). Subsequently collected twigs were placed in plastic bags with side holes, to avoid sweating of the sample, and labeled with site information (no. of sample, location, geographical coordinates, location, etc.) And tree characteristics (species, condition of vigor, tree height, vegetation, phenological stage and persistence of needles of different ages in branches composed of internodes, vegetation type) and finally preserved in snack average temperature of 15ºC, after his laboratory.

Once tissue samples obtained fuck were sent for analysis to a private laboratory duly certified by the Mexican Accreditation Entity (EMA). The analytical techniques and chemical parameters used for needles samples were: for sulfates (SO4) with analytical technique As-20, for boron (B) AS-15, according environmental standard approached for the determination of both parameters by Nom-021-SEMARNAT-2000; for the case of Arsenic (As) trials with hydride generator and under the standard of the Nom-147-SEMARNAT/SSA1-2004.

Statistical analysis was performed using GraphPadInStat software versión 3.06.32(2003) to related the concentration of the three most important contaminants of air pollutions widespread by smoke plumes of the geothermal fields (Wang et al., 2002) and the presence or absence of the Monterey pine aphid colonies on 20 stands monitored.

3 Results and Discussion

3.1 Actual conditions of stands evaluated and forest pests

In general, the presence of main pests and diseases on the 20 stands monitored are directly related to the stand conditions such as species composition and age, and them are independent of if the sites are nearby of any source of fumes of the geothermal wells and moreover on contents of sulphur (S), boron (B) and arsenic (As) on foliar tissues analysed, except for the case of Monterey pine aphid *Essigella californica* (Essig) , as it is seen forward. Fig. 2 shows the percentages of abundance of the main forest pests and diseases associated to each ones of the 20 stands surrounded the geothermal field "Los Humeros, Puebla, Mexico and where the most important are: the dwarf mistletoes (*Arceuthobium gland solobosu* subsp. grandicaule), tip borer beetle: *Pityophthorus aztecus* (Bright) (Coleoptera: Scolytinae), Cone borer: *Conophthorus ponderosae* (Hopkins), The Monterey pine aphid and Pitch canker: *Fusarium circinatum* (Pitch canker).

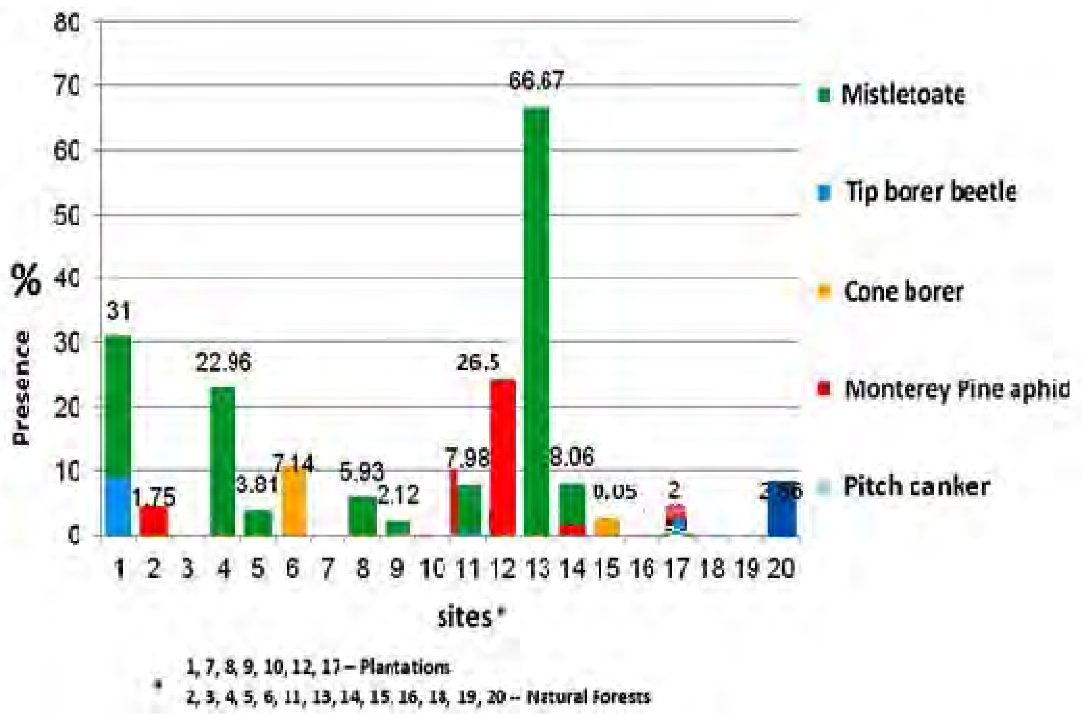

Fig. 4 Percentages estimated of the presence of the main forest pests and diseases registered during the forest health monitoring in the Geothermal field "Los Humeros", Puebla, Mexico.

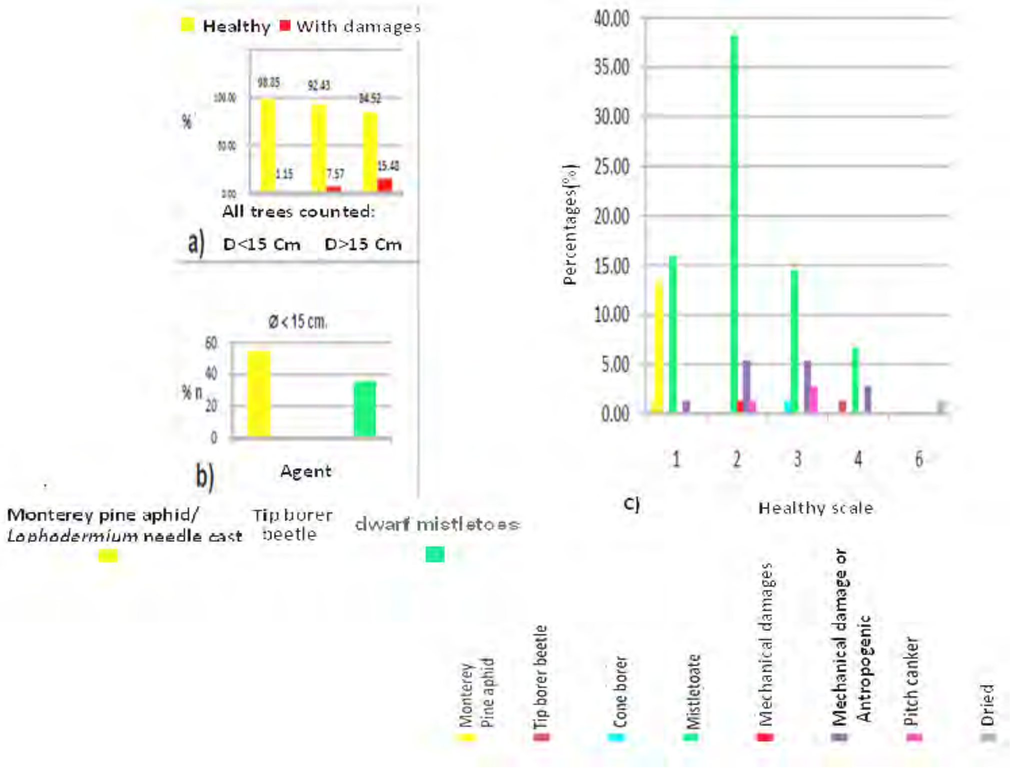

Fig. 5 Total percentages (%) of Pine species(Diameter<15 Cm, >15 Cm) associated with damages by insects, diseases, antropogenic damages and others in the 20 stands monitored.

Furthermore, it is also known that even trees of the same species, age and grow under the same site, physiologically react differently to external physical factors and biological component or with different genetic variability between individuals, and so for example, is observed this response by measuring the retention of needles, premature abortion of buds, erratic growth and presence of symptoms in response to pollutants, soil nutrient deficiencies or answering the activity originated as a result of feeding any sucking insect.

The presence of forest pests (except for the Monterey aphid pine *Essigella califórnica* Essig) and evaluated are independent of the concentrations of different chemical elements obtained from the analysis of 3 pollutant element concentrations of needles and leaves tissue and most effective condition of the sites evaluated.

On the other hand, it is also noteworthy that even trees of the same species, age and growing under one site, physiologically react differently to physical and biological factors external and also with your component or different genetic variability between individuals and thus for example, shows this response by measuring the retention of needles, premature abortion buds and erratic growth symptomatology in response to contaminants, soil nutrient deficiencies either in response to the activity arising as a result of feeding a sucking insect, as is our case *Essigella californica* (Essig).

Forest pests are preferably in stand conditions in place such as quality and quantity of hosts, primarily, not directly related to the condition of vigor and quality index(Del Rio and Petrovitch, 2011), it depends more on the degree of growth of the stands (diameters and shape of the trees crown). The apparent lack of direct correlation pollutants (S, B) emitted from stationary sources of fireplaces geothermal wells and the concentration of these in leaf tissues may be due primarily to the source of variation that involves having used forest species mix for foliar tissue analysis and since each plant has its own capabilities and physiology for fixing through the leaf tissue and translocation of elements and compounds, so it is appropriate to emphasize the need to test with specific forest species bioindicators effective and are used as "markers or tracers" to more accurately perform phytomonitoring contaminants. Also the time of sampling to select those species phytoindicators be made in periods of less physiological activity, ie to obtain leaf tissue for analysis in winter period, in such a way that the discussion here and reduce sources of variation that may contribute to obtain clearer results in this aspect.

3.1.1 Concentrations of substances on the leaf tissue

Table 1 shows the median, minimum and maximum values concentrations in ppm/dm corresponded to contents of 3 substances obtained from 20 needle tissue samples analyzed and representative for each stand monitored.

Table 1 Results of leaf tissue contents of 3 substances monitored.

Substance	Mean	Minimum value	Maximum value	Standard error	Variation coefficient
S, ppm	1373	884.6	1966	72.9	23.74%
B, ppm	167.5	72.22	635.5	32.15	85.5%
As, ppm	0.0025	----------	0.0260	0.001402	142.49%

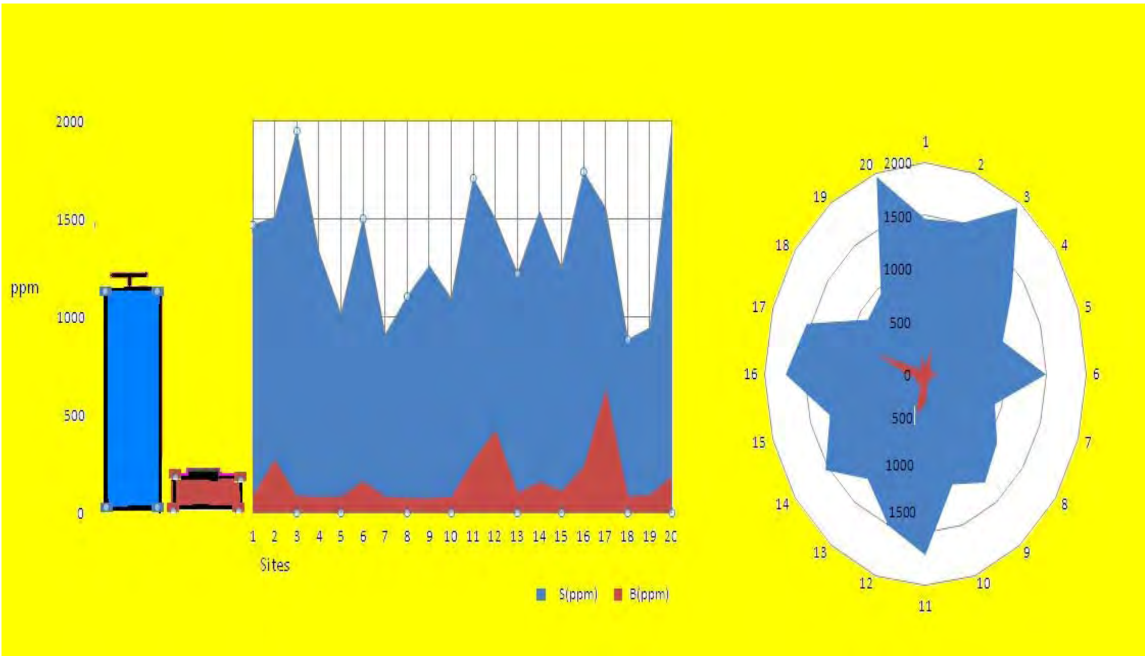

Fig. 6 Representative levels of sulphur and boron (Mean with SEM, left) in leaf tissue from the 20 stands monitored in the Geothermal Field “Los Humeros”, Puebla, Mexico.

The contents of sulphur (S) and boron as results of the leaf chemical contents can be found in Fig. 6. As can be seen, for the case of sulphur (S), 3 and 20 sites were those with greater concentration in leaf tissue with respect to the other sites, however, the statistical analysis gave a value of P> 0.10 and a normal distribution, so that differences in the concentration f this element does not vary significantly between sampling sites, and meeting 75% of the values in the 1550 ppm and 25% in 1098 ppm. Between the content of boron (B) and sulphur (S) relationship is not apparent in their concentrations and foliar sampling sites, in the case of boron that have 25% of their concentrations fall in the average size of 80.19 ppm and 75% at 224.1 ppm, highlighting the sites 12 and 17 as the highest concentration of the element in leaf tissue P value 0.0014 fails the test of normal distribution (alpha = 0.05), so here are significant the differences between the values obtained from the respective sites and described above, similarly to the case arsenic (As) with a P<= 0.0001, where the site 1 and 12 have the largest concentrations.

Of the heavy metals, halides, and non-metals with nutrient and pollutant character (Kratz, 1991, Markan, 1992) analyzed in pine needles, reported than concentrations of sulphur>1,700 in mg/kg dm represent over-nutrition or strong toxic influence as a pollutant, which is a good reference could indicate that our study area there is toxic effects on forest land due to this substance.

In addition, we report here some of the current effects (expressed in forest health visual symptoms described here) that presumably could be exerting the swarming discharged into the atmosphere as a result of geothermal activity that takes advantage and that with time and the dynamics of forest stands , coupled to the greenhouse effect of the earth and site-specific conditions, could change the picture of vigor and trees health by effect cumulative of pollutants in the ecosystem, reducing their growth rates and lead to acceleration processes leading to a dispersion of forest decline; in these places.

When making direct observations and measurements in some pine tree groups growing immediate or nearby the source of the fumes of the geothermal wells where the direct effects of high temperatures besides continuously exposition of these to the CO_2 and SO_4, is common and notorious recording in needles the following symptoms in two ways, either separately or in combination: a mottled yellow bands and tips with brown necrosis down from 10% at baseline on the surface and reaches up to 80-85% of drying before aborting or fall to the ground in full bundles or with the twig of first (more commonly in these conditions and permanent direct exposure) or second year with apical buds dry and very little development in terms of elongation over the age of trees (Fig. 7). It is very common this process is associated with fungal grown needle cast, *Lophodermiun pinastri*, pathogen associated turn to Ozone damage (Costonis, 1968); Gradually the final effect is to see number of trees in defoliation process of partial and total up the drying and death of trees.

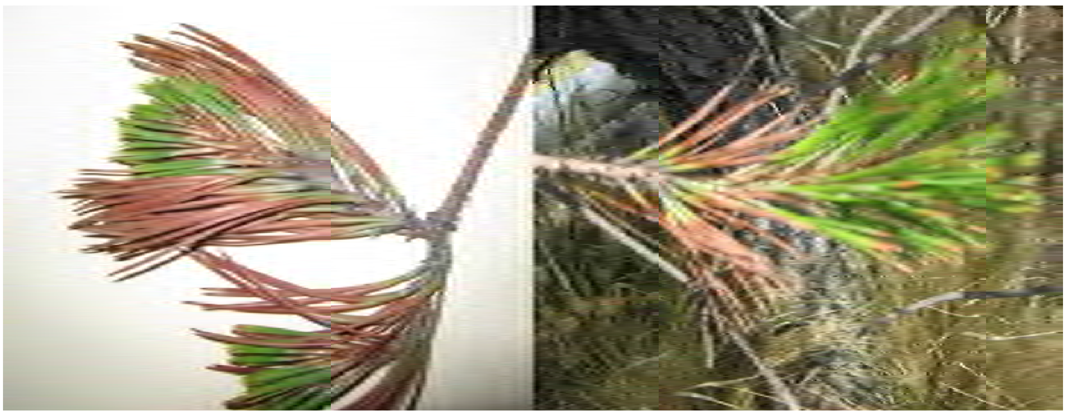

Fig. 7 Direct effects on necrosis needles and premature buds abortion due to high temperatures and continuously exposition to emissions of CO_2 and SO_4 of the fix sources of the fumes of the geothermal wells.

Same process, and less noticeable symptoms was described in more distant forest sites away from fumes geothermal where those due to wind action, contaminants: H_2S, B and As are deposited on trees edges growing together roads and fragmented forests and giving visually call originated the term “edge effects” most likely due to that the trees not protected by others and placed inside the edge of the forest, have greater leaf area with minimum mutual shadow, which brings greater potential for high photosynthetic rates (Krebs , 1985) which may contribute a greater surface deposition of pollutants, translocation and fixation, so that in this way more clearly manifest symptoms and damage to trees, although the results of leaf tissue did not have such a relationship as expressed directly. Already in trees located in central points of the sampled sites on higher trees density in stands this is much less noticeable and can be confused with the natural process of abscission, added symptoms of tip necrosis on needles (Fig. 8) could be associated too with damages caused by ozone (O_3) (Sikora and Chappelka, 2004), damage caused by acid rain or a combination of several of these factors, in the absence of any pathogen or needle diseases.

Fig. 8 Edge effects on tip necrotic needles: possible damages caused by ozone or charge cumulated of air mixed pollutants.

The apparent lack of direct correlation pollutants (S, B) emitted from stationary sources fireplaces geothermal wells and the concentration of these in the leaf tissues may be due primarily to the source of variation that involves having used forest species mixed for foliar analysis as each plant has its own capabilities and physiology for fixing through the leaf tissue and translocation of elements and compounds, so it is appropriate to emphasize the need to test with specific tree species phytoindicators effective and are used as markers or tracers to perform more accurately phytomonitoring pollutants. Also sampling time to select those tree species must be made in periods of less physiological activity, i.e. to obtain leaf tissue for analysis in winter period, in such a way that the discussion here and reduce sources of variation that may contribute to clearer results in this regard.

Forest decline processes have been associated with air pollution, so as chemical group Sulfides have been studied in detail. In this regard, the range of organic and inorganic sulphur gives a better index of the impact which causes Sulphur dioxide in the vegetation. Under heavy air pollution conditions, the sulphur content in conifer foliage increases with time (Dubová and Bublinec, 2006; Materna, 1982; Penka and Cervená, 1985), though sulphur in the foliage rises with the age of the needles, therefore, the age of the foliage is important when it comes to making estimates. Sulphur contents are therefore generally higher in mature needles upper cup portions most exposed. Under short harvesting forests store more sulphide and therefore suggest that exposure of the glass is an important factor influencing the content of sulphur in the leaves. However, use short bring with subsequent increases in tree growth and which in turn can interact increased assimilation of Sulfides from the root.

The sulphur content to the course varies pollution tour (Van der Stegen and Myttenaere, 1991). Atmospheric deposition is the result of high levels of contamination of surfaces, while the Sulphur absorbed through the roots tend to be translocated to the undersides of the leaves. However, it can also give an amount of translocation sulfide carry leaves exposed to unexposed.

Sulfide concentrations were estimated from a study of the elements content in needles of *Picea abies*, which were generally high levels of 0.168% and the upper level of 0.331% was recorded under conditions of Sulfide ore reserves of the place that influenced results. (Evers and Schopfer, 1988). The trend in the concentrations in the needles approach agreed with the concentrations of Sulphur dioxide and a similar pattern has been found in other species (Li and Zhang, 1989). Phytotoxicity problems are expected when Sulphide concentrations exceeding 0.17% (Evers, 1984) or 0.2% (Zöttl, 1985).

In another study in Poland, with the same species (*Picea abies*) plus *Notophagus menziesii* and *Abies alba*, which have been used as good biomarkers in pollutant dispersion mapping based on emission sources, noting that the second-year needles concentration of Sulfides containing more than newer ones in general and forests in high elevations also have the highest concentrations, regardless of the distance at which emission sources are Sulphur dioxide, suggesting that the deposition of sulphur is greater at higher altitudes or that the content of the element in the soil was providing a significant amount (Grezta et al, 1989).

Ammonia and boron were creating serious problems in the brine geothermal to the delta of the river Hardy and it is known that Boron accumulation in plants, insects, and fish have shown that Boron bio-accumulates in plants but does not bio-magnify in aquatic food-chains, according United Nations Environment Programme by International Programme on Chemical Safety, Environmental Health Criteria 204 referent to Boron.

Boron is absorbed by a water flow through the plant roots in the form of non-dissociated boric acid, follows the flow of transpiration, and is transported only in xylem since it is largely immobile in phloem. Ammonia and Boron were creating serious problems in the brine geothermal to the delta of the river Hardy (Austin, 1966).

Boron enters the environment mainly through natural processes and, to a lesser extent, from human activities. from volcanic activity and other geothermal releases such as geothermal steam.

On the other hand, among the content of boron (B) and sulphur (S) is not seen in relation concentrations and foliar sampling sites, for the case of Boron that have 25% of their concentrations fall in the average measured 80.19 ppm and 75% at 224.1 ppm, highlighting the sites 12 and 17 as the highest concentration of the element and leaf tissue P value 0.0014 fails the test of normal distribution (alpha = 0.05), so here are significant differences between the values obtained at the respective sites and described above, similarly to the case Arsenic (as) with P<= 0.0001, where the site 1 and 12 have the greatest concentrations, as for chlorides (Cl) with P=0.0207, with sites 5, 6, 14 and 15 in high concentrations vegetable plants, Sodium (Na), with P=0.0230 without normal distribution with equal values at the sites 6, 10 and 11 and the maximum element in the vegetation growing at the site 20.

Other heavy metal in leaf tissue analyzed was the arsenic (As), whose uniform minimum concentration for the 22 sites was 0.004 ppm.

3.1.2 Association Monterey pine aphid and boron on the needle tissue

The Monterey Pine Aphid is a native of North America, its distribution ranges from southern British Columbia in the north to southern Mexico, it eastern range extends to Nebraska, it is also found as far south as Florida in the southeast (Palmer, 1952; Elmsavers A Division of Environmental Tree Technologies P/L, 2010) .In our study area, *Pinus teocote* (Schiede ex Schltdl) and *P. montezumae* (Lamb) on that order were the main hosts.

It is a recent introduction to Europe and has been identified in both France and Spain; it has also been identified in New Zealand and Southern Brazil. The Monterey pine aphid was first recorded in Australia in March 1998 on *Pinus Radiata* near Canberra; it is now present in all areas across Australia were pine trees are grown (Flynn et al., 2003).

In the geothermal field “Los humeros”, Puebla, Mexico, colonies of *Essigella californica* (Essig) were collected for proper identification (Blackman and Eastop, 1994) and in the forest were observed both as apterous and winged individuals andin groups of 6-8 feeding on second year needles second year of growth (Fig. 9).

Fig. 9 *Essigella californica* (Essig), winged adult and wingless specimens on pine needles.

As can be seen in Fig. 4, the presence of the pine aphid generally agrees on sites which detected the highest amounts of Boron in the leaf tissue except Site 17(<2% incidence of pine aphid) with the biggest concentrations of this element (Fig. 6), spite of where the forest was represented by 100% by regeneration composed of natural pine seedlings less than 15 cm diameter.

At all sites where the incidence of pine aphid per tree was registered, this more is highest on the site 12(26.5%), following the sites 11(10%), 17(2%) and site 2(1.75%) and other ones with minimal occurrence (site14), besides Monterey pine aphid has high incidence in the natural regeneration *of Pinus teocote* and *P. montezumae* (Fig. 5b), although the presence of this insect is distributed only on trees of vigor category number 1 (Fig. 5c) .

Table 2 shows the concentrations obtained from the leaf tissue of sulphur (S), boron (B) and arsenic (As) in ppm and the presence of Monterey pine aphid in the 20 stands evaluated.

The model is broken according to general equation, R squared and P value, as indicated in Table 3.

Table 2 Relation of stands monitored and concentrations of 3 substances in leaf tissue with the presence of Monterey pine aphid.

STANDS	Variable x_1	Variable x_2	Variable X_3	Variable Y
	S(ppm)	B(ppm)	As(ppm)	Mont Pine Aphid
1	1470.837	81.973	0.014	**
2	1509.746	270.386	0.005	*
3	1950.908	85.038	0.005	**
4	1332.879	78.890	0.008	**
5	1015.576	80.150	0.005	**
6	1502.715	160.012	0.004	**
7	910.555	80.303	0.000	**
8	1104.424	73.503	0.005	**
9	1263.331	72.218	0.000	**
10	1095.254	79.171	0.000	**
11	1708.892	268.075	0.001	*
12	1501.092	420.693	0.026	*
13	1221.762	101.967	0.000	**
14	1539.521	154.768	0.000	*
15	1251.164	110.145	0.000	**
16	1741.292	236.177	0.000	**
17	1554.137	635.462	0.008	*
18	884.591	83.541	0.002	**
19	944.341	89.355	0.002	**
20	1966.041	187.728	0.003	**

Presence(*)

Absense(**)

Table 3 Regression multifactorial test showing the relationship between the presence of Monterey pine aphid with concentration of 3 substances on needles tissue in the geothermal area: “Los Humeros”, Puebla; Mexico.

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[D:Mont Pine Aphid] =  -0.2037 +  5.209E-05*[A:S(ppm)] + 0.002249*[B:B(ppm)]
     + 1.251*[C:As(ppm)]
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Variable	Coefficient	SE	95% Confidence Interval
(constant)	-0.2037	0.3201	-0.8823 to 0.4749
A:S(ppm)	5.209E-05	0.0002466	-0.0004707 to0.0005749
B:B(ppm)	0.002249	0.0006104	0.0009550 to0.003543
C:As(ppm)	1.251	12.949	-26.201 to 28.703

R squared = 56.61%.

P value is 0.0033

Variable	t ratio	P value	Significant?
(constant)	0.6364	0.5335	No
A:S(ppm)	0.2112	0.8354	No
B:B(ppm)	3.685	0.0020	Yes
C:As(ppm)	0.09663	0.9242	No

As is possible appreciate above, the variable B (boron) is directly significant respect to the dependent variable (y) named as Monterey pine aphid, which let us conclude preliminary about it and these results suggest the use of Monterey Pine aphid *Essigella californica* (Essig) as bioindicator of polluted sites , however it is necessary to continue the observations in the study area organizing forest healthy monitoring for long time and the changes hope on the cumulate pollution and its effects on forest vigor condition and stress and the incidence of pests in stands surrounding the geothermal area “Los Humeros”, Puebla, México.

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