

# I. TEISĖSAUGOS PAREIGŪNŲ IR PRIVAČIŲ SAUGOS STRUKTŪRŲ DARBUOTOJŲ MOKYMAS

## SOMATIC AND PSYCHICAL DISEASES AND HUMAN BEHAVIOUR IN RELATION TO GEOLOGICAL FACTORS

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## Abstract

A human health is influenced by complex interaction of different factors. Impact of the geological environment is still scarcely acknowledged. Four groups of geofactors are analysed in the country scale (1) gravity and magnetic fields, (2) concentration of geochemical elements in the soil, (3) tectonics and soil lithology, (4) landscape (relief, woods, drainage network, wetlands). These groups do not encompass whole spectra of geofactors that may have an influence on the human health, but are recognised as possibly being of primary importance. The medical and human behaviour parameters list the schizophrenia, suicides, homicides, alcoholic psychosis, drug addicts, crimes. As far the study considers very different parameters involved, a statistical method was applied that ensures objective identification of existing relationships. The different data formats were unified using GIS techniques that allowed scaling of geological databases to 45 administrative regions.

Schizophrenia is shown to positively correlate with the magnetic field, in other words, the higher is magnetic field the higher is a disease risk. By contrast, the gravity field intensity correlates negatively with the crime distribution. The tectonic zones recognised in the potential fields maps seems to have some influence on the homicide distribution. The landscape has only a minor influence. The differentiation of the relief (hilly areas) statistically increases the alcoholic psychosis. Some geochemical elements contained in the soil have statistically strong correlations with some diseases and human behaviour. Schizophrenia and suicides are "remedied" by P-, Pb-, Sn-, Y-, Yb-rich environments. It is notable that only one medical parameters of six analysed, i.e. drug addicts, do not show any statistical correlation with geological factors, whereas the others indicate clear relationship to particular geofactors.

Different geological processes are very closely interrelated, such as different types of the earth's crust having different characteristics of the potential fields significantly influences processes accounted for formation of the present landscape and (sub)soil lithologies, as well as geochemical elements often reflect particular lithological groups typical for particular geological conditions. Still, obtained strong statistical correlations undoubtedly point to significant role of geofactors as regards human health.

## 1. Introduction

A human health is influenced by a number of factors of different nature (e.g. Cannon, Hopps, 1970; Draggan et al., 1987). Geomedicine has roots that go back centuries; papers appeared in the nineteenth century noting geographical patterns in distribution of disease. However, many areas of the subject are relatively new for different related reasons.

Some geological factors were studied with relation to human health in Lithuania. The natural factors are grouped as following (1) earth's potential fields, (2) landscape, (3) geological factors, (4) geochemical elements. The human behaviour and somatic diseases investigated list suicides, homicides, drug addicts, crimes, schizophrenia, alcoholic psychosis. The study was performed at a country-scale.

It is conventionally realised that geochemical elements have some impact on human health. As show the geochemical studies the distribution of elements in the soil is rather variable across Lithuania, depending on human induced pollution, natural background related to the soil and sub-soil types, vegetation, and relief. The deficiency or excess of chemical elements in the living environment can negatively influence the human health, whereas presence of other elements can have a positive impact. Also, the landscape may have a certain role as the psychological environmental factor. The most controversial is the influence of the earth's potential fields, though sometimes stressed as an important factor to be accounted for. Commonly potential fields are considered as being of too low intensity to have any discernible impact on the human health. Other investigators still argue that natural potential fields may have even greater influence than the human-made intense electromagnetic fields.

The geomedicine studies mainly concerns influence of the geological environment on the human health, whereas the human behaviour is less considered with this respect. The acknowledgment of the psychological effects of environmental contamination started from studies people's reactions to natural disasters in the 1950s. It was recognized that people exposed to various natural disasters (e.g., hurricanes, floods, earthquakes) could develop psychological sequelae from the stress such as major depression, chronic anxiety, and post-traumatic stress disorder (Baum et al., 1992). Current thought among disaster relief workers holds that most people will suffer no or only transient effects from the stress of a natural disaster (i.e., acute stress disorder or, "people reacting normally to an abnormal situation"). There are important differences between psychological effects from exposure to chemicals and those resulting from natural disasters. Life near a hazardous waste site is a more nebulous and uncertain situation. Exposures to neurotoxic chemicals can cause psychological changes, so it is important to rule out exposures before declaring a health problem to be solely psychologically based (Dayal et al, 1994). Testing shows greater occurrence of depression, anxiety, and somatic symptoms in the exposed population versus the control population.

Lithuania is characterized by rather low intensity of hazardous geological processes as well as absence of high-risk industrial objects (with some exceptions, as Ignalina NPP). Still, the living environment that at first look seems to be stable and invariable across the country may have certain impact on the human health and behavior. The knowledge and recognition of those relationships is an important issue for developing of the control population.

## 2. Data and methods

Statistical data on distribution of afore-listed six groups of diseases were collected for the whole territory of Lithuania for the year 1999. The data (events per 100,000 population) are averaged for each administrative region numbering 45 in total. As far the maps of the geological factors are designed in a different way (isolines, polygons) a special technique has to be developed to assist re-calculation of average intensities of geofactors to separate

administrative regions. For the better visualisation of distribution of the disease events, the contour line maps were compiled, similar to the way the geological maps are constructed. Vice versa, the conventional geofactor contour line maps were scaled to administrative regions.

The digital model of the gravity and magnetic fields are stored at the Lithuanian Geological Survey (Korabliova, Popov, 1998). The average intensities for each administrative region were recalculated from conventional maps (Fig. 1) using geographic information system (GIS) tools (Belickas, Denas, 2000). Also, the variability of the earth's fields is regarded as potential factor, therefore was accordingly calculated using standard statistical methods (standard deviation, etc.), also the horizontal gradients were derived from the field maps. Additionally, the maximum and minimum field intensities were computed for each administrative region.

The landscape is considered as a potentially active psychological environmental factor. Different parameters such as slope gradients, relief differentiation (variability), altitudes, maximum and minimum altitudes were calculated from the digital terrain model of Lithuania using GIS tools (Denas et al., 2004). The other landscape factors accounted are percentage of the woods, lakes, rivers, and wetlands in the each administrative region. These factors were obtained from the CORINE GIS model available at the Lithuanian Geological Survey.

The analysed geological factors consider the neotectonic faults, hydrogeochemical anomalies of the shallow aquifers that are considered to reflect the present fault activity (Sliupa, 2002), clayey and sandy sub-soil lithologies (Guobyte, 1999). These factors were also processed using GIS tools. The fault density map was calculated at the administrative regions scale (Fig. 2). The hydrogeochemical anomalies are believed to reflect the present activity of the tectonic faults.

28 trace elements (Zr, Zn, Y, Nb, etc.) were analysed. The average concentrations of the geochemical elements in the soil (Kadunas et al., 1999) of the each administrative region were recalculated using the same GIS techniques.

An application of GIS tools is crucial in presented study. GIS technology makes it possible to link, or integrate, information that is difficult to associate any other way. It is capable of performing a wide range of information processing and display operations (e.g., map production, data analysis, and statistical modelling). Thus, GIS is a valuable tool for integrating and analyzing disparate data sets. Any variable that can be located spatially can be entered into a GIS. For example, an area feature of the earth (e.g., a lake) can be linked to the attributes associated with the feature (e.g., salinity or depth of the lake). A GIS can also convert existing digital information that is not in map form into recognizable and usable forms. For example, statistical information on diseases level in different administrative regions can be analysed to produce a map-like layer of digital information. A critical component of a GIS is its capability to conduct complex spatial analyses and produce visual images.

A statistical analysis was performed for each geofactor with confidence level 0.95. Correlation coefficients were obtained that show absence or presence of relationships between the different parameters. Therefore, defined relationships are considered as statistically significant and consistent. This approach ensures an objective analysis of data avoiding any prejudiced implications.

### **3. Distribution of the somatic diseases and human behaviour in Lithuania**

Six disease groups were analysed. They show uneven distribution composing large minimum and maximum clusters that argue against random pattern, rather implying certain factors contributing to a state of the human health, as it is also recognised in other regions (e.g. Sauer, Brand, 1971; Villanueva W., 1982).

The schizophrenia indicates increased number of disease events in the north-east of Lithuania (>600 cases for 100,000 population) (Fig. 3). In the west the distinct NW-SE trending zones are defined with the maximum encompassing Plunge, Telšiai, Kelmė, Raseiniai regions. This maximum borders with the distinct minimum of Šiauliai, Radviliškis, Kėdainiai, Jonava regions. The other maximum is identified in the Kaišiadorys, Kaunas, Marijampolė, Vilkaviškis regions. The most intense anomalies are reported from the Pakruojis, Anykščiai ir Ignalina regions, while the lowest values of schizophrenia events are identified in Trakai-Šalčininkai-Varėna area and SW Lithuania.

The alcoholic psychosis shows different pattern from the described above (Fig. 3). It is most common in west Lithuania with maximum in Plungė, Šilutė, Vilkaviškis regions. The north central Lithuania indicates a reverse tendency (roughly five time less number of events). In a regional scale, the central part of Lithuania from Druskininkai to Biržai region is marked by decreased number of alcoholic psychosis events.

The drug addicts distribution has less regular shape, anomalies are rather randomly scattered across Lithuania. Two highest anomalies are reported from the Biržai and Tauragė regions (Fig. 3).

Crime events have more evident regional trends. Some north-south trending anomalies are discernable (Fig. 3). A distinct maximum extending from Pakruojis region in the north to Marijampolė region in the south punctuates the central Lithuania. A similar maximum is defined in west Lithuania. These maxima are separated by zone of minimum values reported from Joniškis in the north down to Jurbarkas region in the south. The eastern part of Lithuania is also characterized by lower number of crime events, except Vilnius area.

No distinct variations are recognised in the distribution of the suicides in Lithuania, the values ranging mainly from 25 to 75 (per 100,00 population) (Fig. 3). Still, 3 very high anomalies are documented in Pakruojis, Kupiškis and Alytus regions (>100 cases). Similar to the crime distribution, some north-south trends are discernable. An increased number of suicides are traced from Kupiškis region in the north to Druskininkai region in the south. West and east of this anomalous belt the minimum values are registered (respectively, Raseiniai-Marijampolė and east Lithuanian areas).

The homicide distribution shows quite regular pattern (Fig. 3). A very distinct minimum zone extending NE-SW is identified in west Lithuania from Joniškis region to Šilutė region. It borders with clear Pakruojis-Jurbarkas maximum that merges with other NW-SE trending Panevėžis-Šalčininkai maximum. It should be noted that homicide distribution has some reverse correlation with suicides.

## **4. Results**

### **4.1. Potential fields and human health**

Gravity and magnetic fields show considerable variations across the country. The maximum intensity of the gravity field is mapped in southeast Lithuania, south Central Lithuania, north Lithuania, whereas minimum values are documented in west and central Lithuania (Fig. 1).

The magnetic field is more differentiated compared to the gravity field. An increased intensity of the magnetic field is reported from east and southwest Lithuania, minimum intensity is identified in central and west Lithuania. Differentiation of the fields also varies considerably, maximum gravity variations are defined in Joniškis, Šiauliai, Vilnius, Švenčionys regions, maximum magnetic variations are recognised in Rokiškis, Ignalina, Tauragė regions.

It should be noted that the gravity and magnetic fields do not have any distinct correlation. Often it is even of reverse trend. It is related to different sources of the gravity and magnetic fields. The former is mainly contributed by deep geological masses, whereas

the latter reflects shallower geological bodies. Accordingly, the gravity field is less differentiated than the magnetic field.

The horizontal gradient maps reveal the variability of the potential fields (Fig. 4). Distinct linear zones are identified, that mark important lithological or tectonic boundaries. An increased differentiation of the magnetic field is reported from the southeast and southwest Lithuania, whereas only little varying in the west. The gravity gradient anomalies are mainly concentrated in the southeast and north Lithuania.

Two of six analysed medical parameters have consistent statistical correlation with intensity of the magnetic and gravity fields, whereas variability of the earth's fields is devoid of any significant statistical correlation. Schizophrenia is shown to positively correlate with the magnetic field, the coefficient of correlation is as high as +0.30, in other words, the higher is magnetic field the higher is the disease risk (Fig. 5).

By contrast, the gravity field intensity correlates negatively with the crime distribution. The coefficient of correlation is very high -0.43. It means that decrease in the gravity field intensity associates with increase in crime activity. The most distinct positive crime anomalies in southwest of west Lithuania and in central Lithuania are confined to distinct gravity minimums. In geological terms, they coincide with large granitoid intrusions. The central Lithuanian granitoid massif is only little studied by boreholes, whereas the SW Lithuanian intrusion of granitoids is rather well investigated (Motuza et al., 2004). It is represented by very specific granitoid massif characterised by high magnetic susceptibility, low density and high radioactivity.

The statistical methods somehow fail to reveal existing relationships, as evidenced by comparison of the homicide distribution with the magnetic field map. A very distinct NE-SW trending anomaly in west Lithuania marks the first-order Tauragė-Ogrė fault zone. Similarly, the NW-SE oriented maximum marks the other large-scale Vilnius-Mažeikiai tectonic zone. The Zarasai maximum is confined to distinct Daugavpils block. South of it, the west-east trending minimum is related to the Polock tectonic zone. Therefore, it is suggested that large-scale tectonic zones somehow impacts the homicide distribution in Lithuania.

## 4.2. Landscape and disease risk

Landscape has a considerable impact on human psychological state (psychological ecology). Also, it causes and/or reflects different associating factors, as climate, susceptibility to pollution, type of ground water, etc. that also may impact the state human health. Therefore, the variations in altitude or dissection of the relief, vegetation type, drainage network can be considered as either direct or indirect factors.

The Lithuanian territory is characterized by low relief. Still, some distinct orthographic regions are defined that show different altitudes and landscape dissection. The SE Lithuania is dominated by hilly landscape of higher altitudes (100-200 m above sea level) that is attributed to Baltija High composed by marginal moraine. Similar relief is restricted to the Žemaitija High of central part of west Lithuania. These two topographic highs are separated by central Lithuanian Low. The low relief dominates the seaside area.

Most of analysed factors (drainage system, woods, wetlands) do not show any statistical correlation with the human health. An exception is the differentiation of the relief that has a positive statistical loading on the alcoholic psychosis, the correlation coefficient is as high as +0.36 (Fig. 6). Accordingly, this kind of disease is more widespread in the eastern and western Lithuanian orthographic areas. The minimum disease level is confined to the topographic lows, such as Druskininkai-Biržai minimum separating Baltija and Žemaitija topographic highs.

Similarly to afore-described homicide vs. magnetic field relationship, no consistent statistical correlation is defined for the schizophrenia, though comparison of maps (Fig. 6) insist on some correlation with the topography. Thus, the Plungė-Raseiniai maximum is

clearly confined to the Žemaitija topographic high. In other places this correlation is of more complex character.

#### **4.3. Geological factors and disease risk**

No one of geological factors analysed shows any significant statistical correlation with diseases. However we cannot be sure that neotectonic faults, their activity, sub-soil lithology has no impact on the human health. The absence of correlation may be related to too rough grouping of those factors. We did not apply any ranking of faults and criteria of their activity, also the defined sub-soil lithology groups seems to be too general. The importance of the latter factor is hinted by obtained close correlations of human diseases with geochemical elements having similar petrogenic associations (Šliaupa et al., 2004).

The maximum density of tectonic faults is identified in north Lithuania, W-E trending zone extending from Šakiai to Vilnius, the northeast striking zone ending from Zarasai to Švenčionys region (Fig. 2). These zones are confined to well known tectonic fault swarms.

#### **4.4. Soil geochemistry and disease risk**

The major source of the body's trace elements is the soil. There are various pathways through which the trace elements find their way into the body. The concentrations of trace elements in rocks vary by rock type and location and are a fundamental control on the availability of trace elements to humans (Pier, Bang, 1980). Commonly the clayey lithologies are more rich in magnesium, iron, sodium, potassium, manganese than sandy soil, whereas sands contain higher concentrations of titanium, phosphorus, chromium, lead, nickel, cobalt (Adriano, 1986).

Trace-element concentrations are modified by a variety of natural processes and deliberate and accidental human activities. Agricultural chemicals and pollutants may be added. Crops selectively remove from the soil the elements they require for growth. Animals intensify this selectivity by consuming only certain parts of plants for food. Methods of processing and storing food further change its composition. The drinking water contains trace elements leached from rock and soil and may also have been polluted or chemically treated.

Of twenty-eight geochemical elements analysed in presented study, the five elements show distinct statistical correlations with diseases and human behaviour. They can be divided into two groups with respect to their geochemical associations.

Lead, phosphorus and tin are shown to have negative correlation with the schizophrenia (Fig. 7). The coefficients of correlation are defined respectively -0.40, -0.38 and -0.40. Those are very high values that persuade important genetic relationships. Those three elements have rather similar distributions in the soil across the Lithuanian territory, with some increase in west and east Lithuania. They compose a common petrogenic group that suggests association with the same soil lithologies. Average concentrations of lead and phosphorus are the highest in the sandy soil lithologies (10 per cent higher concentration than in the clay) with the maximum in pit in Lithuania. The tin indicates increasing trend from sand to clay, and is rather low in the pit.

The second group is represented by yttrium and ytterbium. They are geochemically very similar therefore reflect the same lithologies of the soil. These two elements have negative loadings on the suicide distribution, the coefficient of correlation is respectively -0.35 and -0.37 (Fig. 8). In other words, the increase in concentration of Y and Yb in soil decreases the suicide risk. The highest concentrations are identified in central Lithuania and along the northern border with Latvia. In terms of soil lithologies, the maximum concentrations are identified in clay, while being minimum in sand (difference is about 1.7 times).

The geochemical enrichment index was calculated for different soil lithologies (clayey, clayey-sandy, sandy, pit). A close correlation of the suicide distribution is recognised for the geochemical enrichment of sandy lithologies. Correlation coefficient as high as +0.31 indicates that increase in concentration of the chemical trace elements increases the suicide risk. The afore-mentioned three distinct suicide anomalies (Pakruojis, Kupiškis and Alytus regions) are related to geochemical enrichment anomalies (Fig. 9). A similar positive statistical correlation was identified for the schizophrenia and geochemical enrichment of pit (Fig. 9). The coefficient of correlation is rather high +0.39.

## 5. Conclusions

The human health and behaviour is shown to have some statistical correlation with the earth's fields. This relationship is rather strong as regards intensity of the magnetic and gravity fields. This influence is, however, of different type, it may be positive with respect to some diseases, whereas negative with regard to the others. Schizophrenia is shown to positively correlate with the magnetic field (coefficient of correlation +0.30), in other words, the higher is the magnetic field the higher is the disease risk. By contrast, the gravity field intensity correlates negatively with the crime level. The coefficient of correlation is very high - 0.43. The tectonic zones recognised in the potential field maps seems to have influence on the homicide distribution, which is however of different nature for different tectonic zones.

The landscape has only a minor influence. The differentiation of the relief (hilly areas) statistically increases the alcoholic psychosis. This influence though can be due to other factors that directly correlate with the relief.

So far, no traditional geological factor has been identified to impact the human health, though this may be a result of too rough grouping of factors.

Some geochemical elements contained in the soil statistically influence the human health and behaviour. Schizophrenia and suicides are "remedied" by P-, Pb-, Sn-, Y-, Yb-reach environments. These elements show different lithological associations.

It is worth of noting that only one medical parameters of six analysed, i.e. drug addicts do not show any statistical correlation with geological factors, whereas the others indicate clears relationship to particular geofactors.

It should be cautioned however that obtained correlations do not necessarily unravel the genetic relationships between studied factors. They may be directly related to other factors not well understood as yet. For instance, the earth's fields reflect the deep structure and type of the crust that has a considerable impact on other geological environment such as the present relief, tectonic activity, etc. The distribution of geochemical elements in the soil is also related to a number of other factors, such as the sub-soil lithology, vegetation type, soil erodibility and so on that, in turn, may be the positive or negative parameter as regards human state. Also, the metabolism should be taken into consideration. For example, the afore-discussed tin affects the metabolism of other metals such as copper, zinc, and iron; therefore, if the levels of these metals are not optimally regulated, it is difficult to ascertain whether a specific effect is caused by exposure to tin itself or is due to fluctuations in levels of other metals.

The presented study is considered as the first attempt to recognise relationship of human health to earth's factors. The GIS approach has proved to be of very high efficiency in combining and analysing big amount of data representing very different type of factors. Analysis is not limited to any kind of information, therefore studies may be expanded in terms of both adding new parameters and running more detailed studies of selected key areas.





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## FIGURES

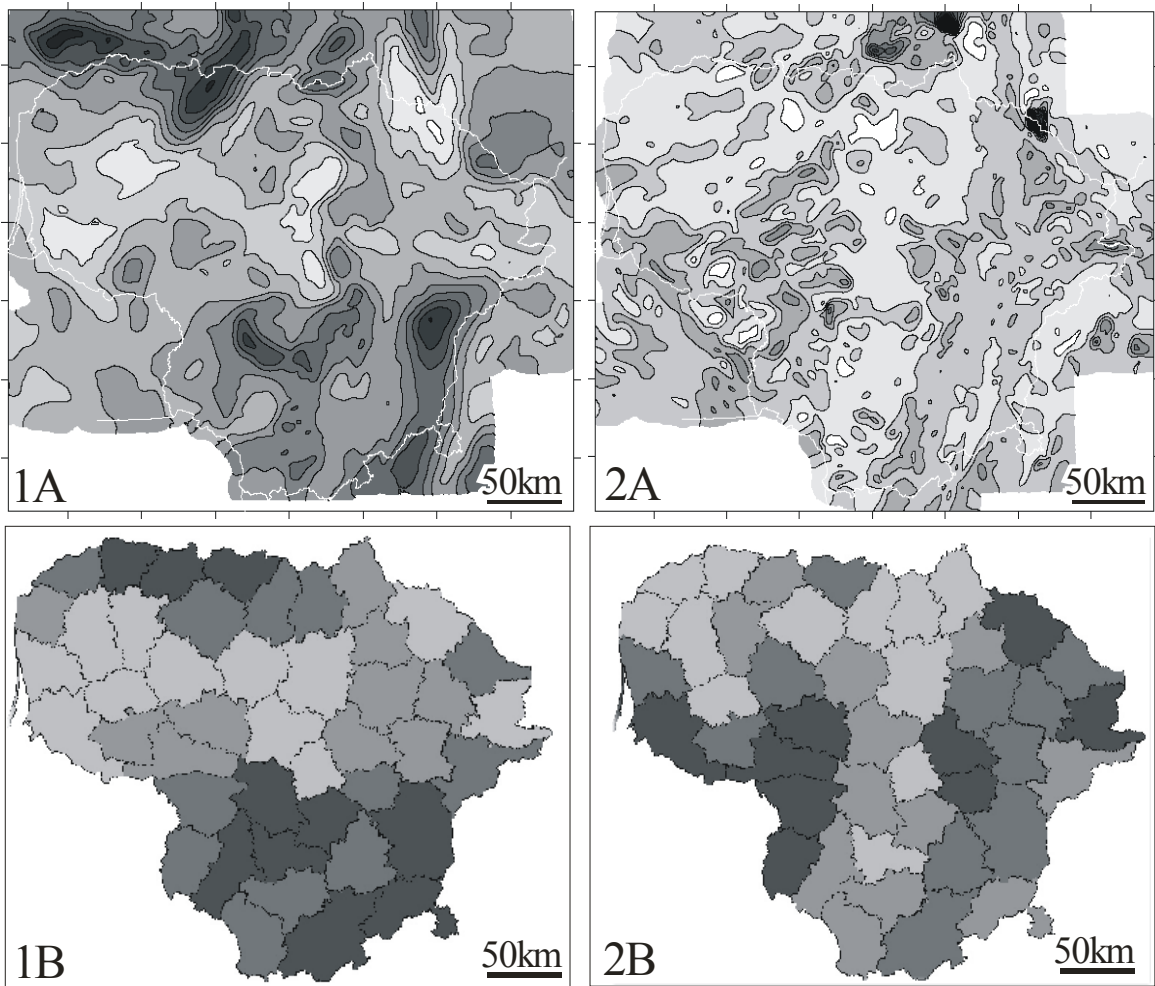


Fig. 1. Conventional gravity and magnetic fields maps of Lithuania (1A, 2A) scaled to administrative regions (1B, 2B) using GIS. The grey colour scale indicates increasing intensity from white to black.

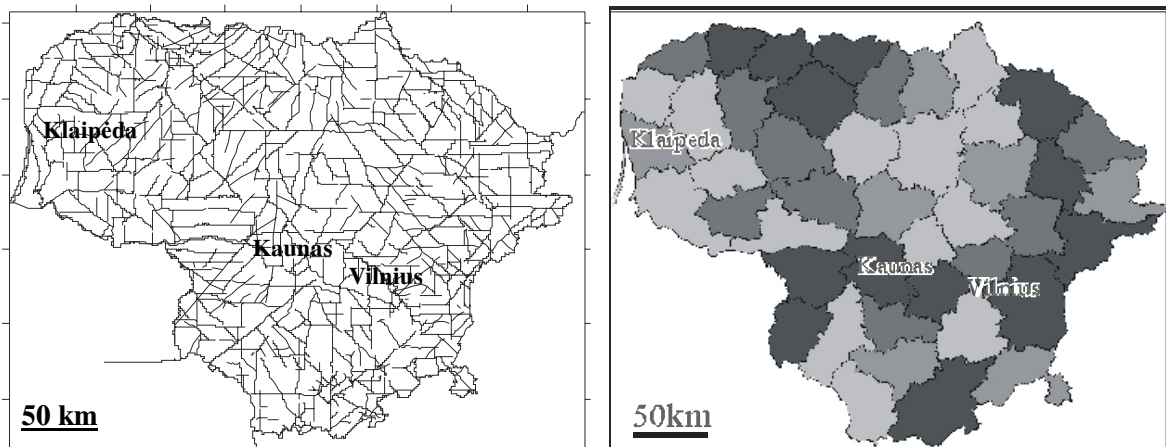


Fig. 2. Recalculation of the neotectonic lineaments (faults) of Lithuania (left) to fault density in administrative region scale (right). The grey colour scale indicates increasing intensity from white to black

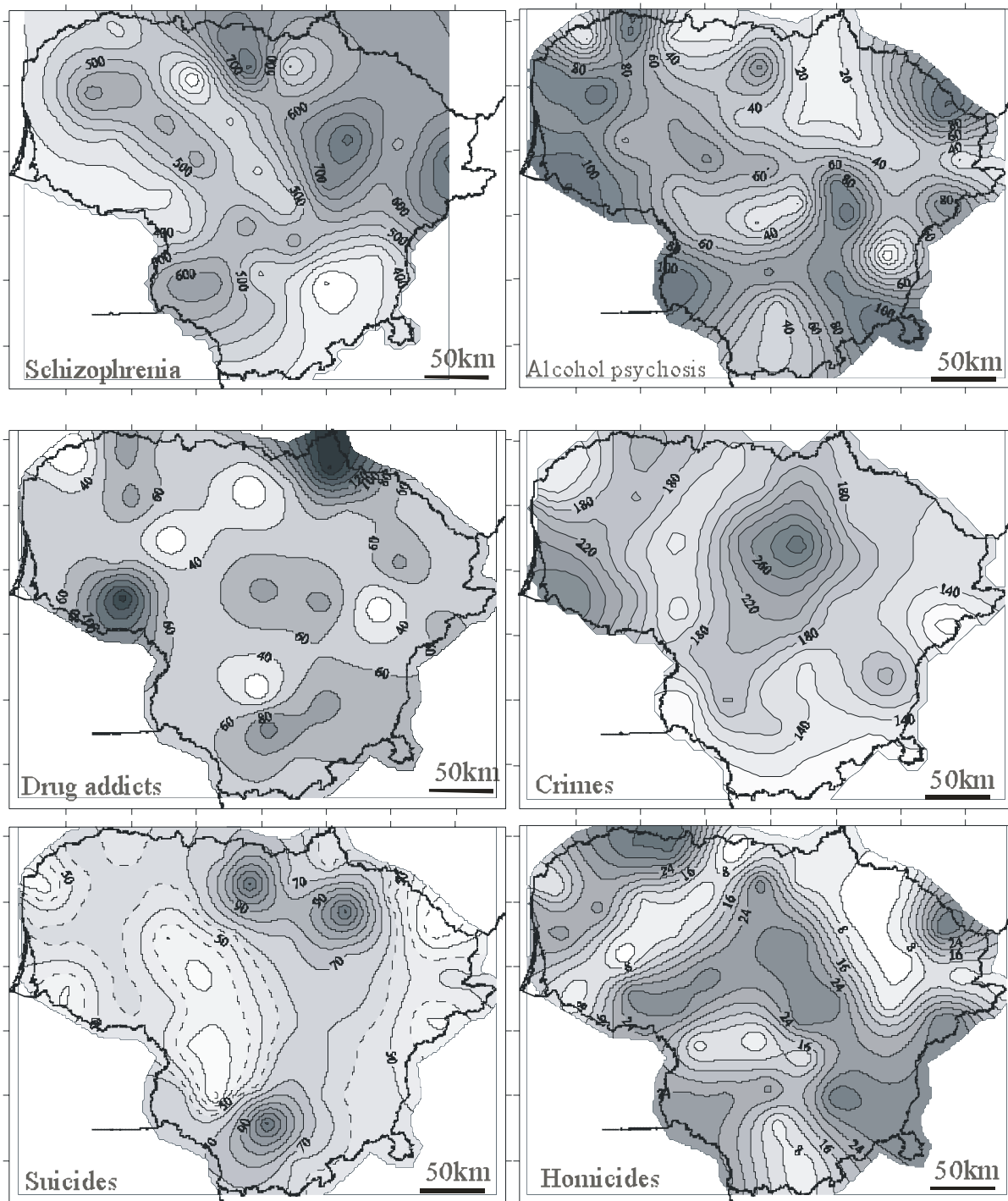
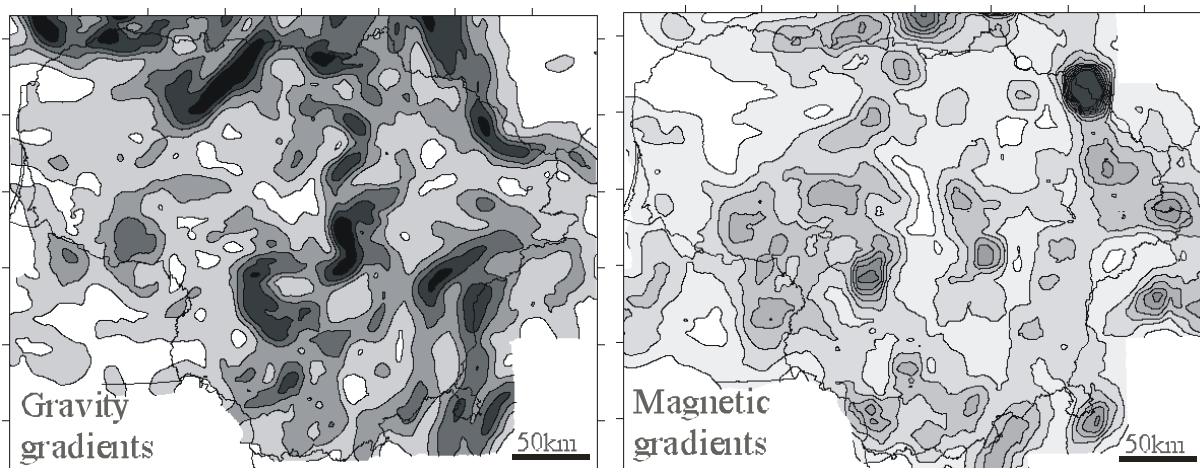
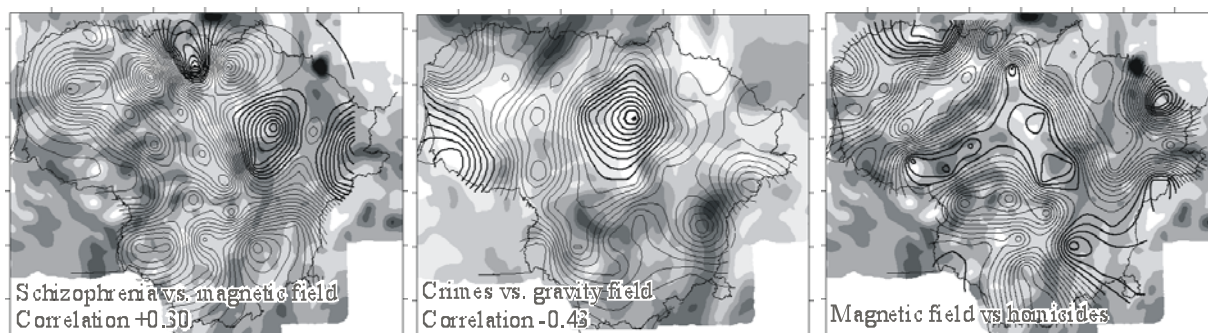


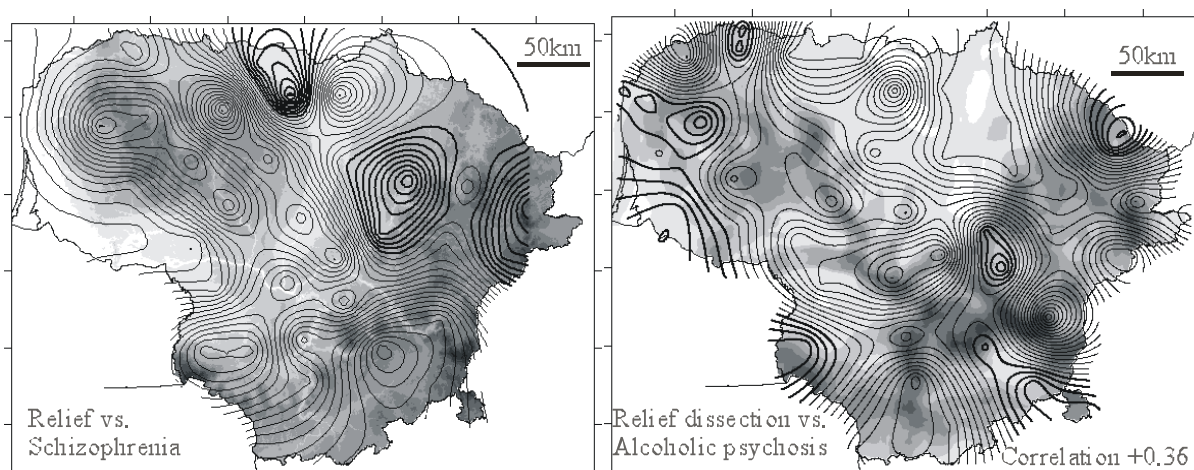
Fig. 3. Distribution of schizophrenia, alcoholic psychosis, drug addicts, crimes, suicides and homicides in Lithuania. The grey colour scale indicates increasing intensity from white to black.



**Fig. 4. Horizontal gradients (variability) of the gravity (left) and magnetic (right) fields. The gradients are averaged with low-pass window. The grey colour scale indicates increasing intensity from white to black.**



**Fig. 5. Comparison of the gravity and magnetic fields with schizophrenia, homicides and crimes. The grey colour scale indicates increasing intensity of earth's fields from white to black. The medical parameters are presented by contour lines.**



**Fig. 6. Comparison of relief to schizophrenia and alcoholic psychosis. The grey colour scale indicates increasing relief amplitudes from white to black. The medical parameters are presented by contour lines.**

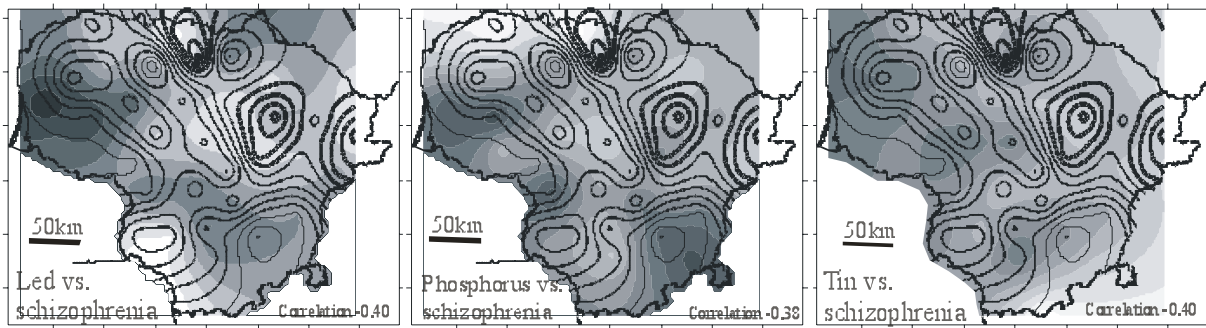


Fig. 7. Comparison of schizophrenia with concentration of lead, phosphorus and tin in the soil. The grey colour scale indicates increasing concentrations of geochemical elements from white to black. The medical parameters are presented by contour lines, the thickness of lines indicate increasing rate of events.

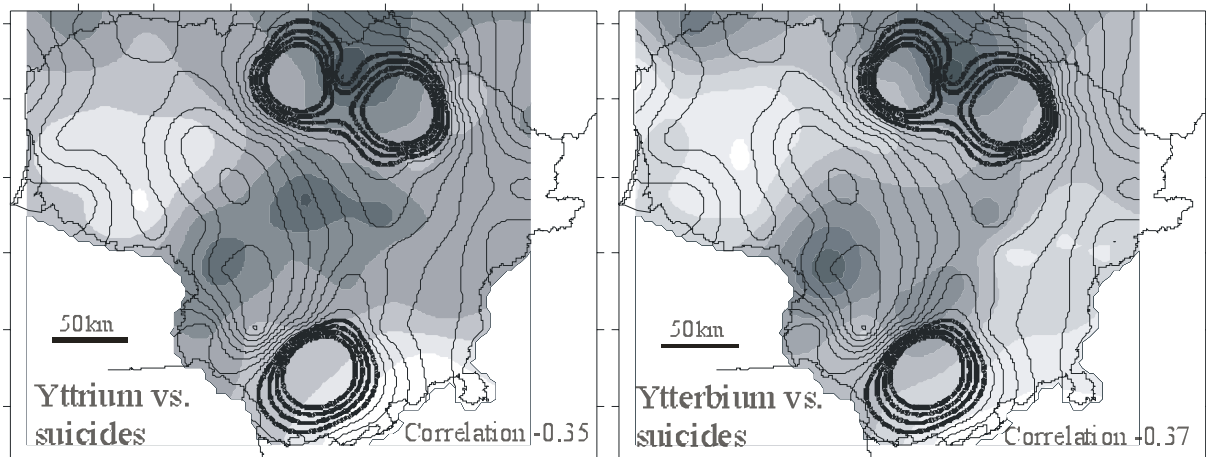


Fig. 8. Comparison of suicides with yttrium and ytterbium concentrations in the soil. The grey colour scale indicates increasing concentrations of geochemical elements from white to black. The medical parameters are presented by contour lines, the thickness of lines indicate increasing rate of events.

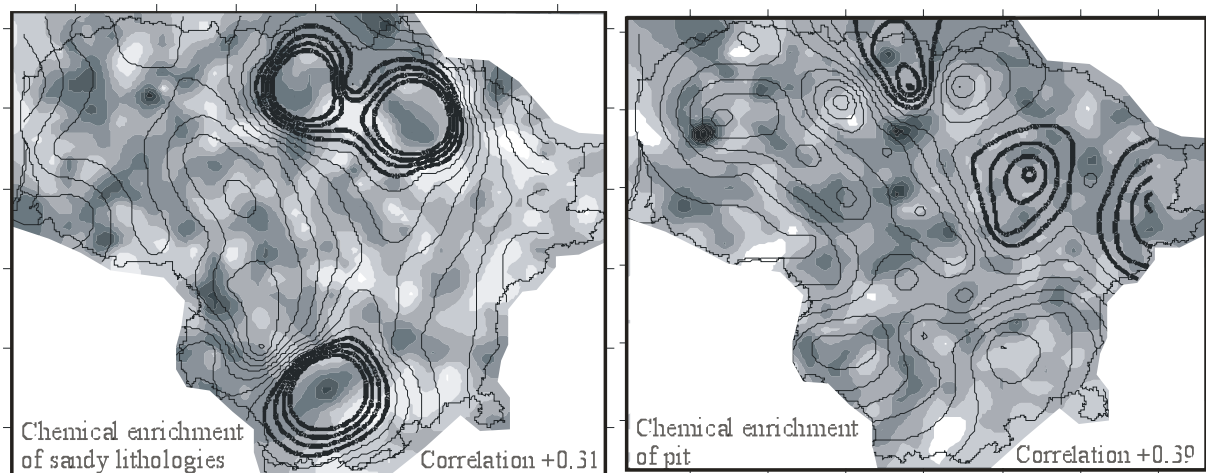


Fig. 9. Comparison of suicides and schizophrenia with respectively geochemical enrichment of soil sandy lithologies and pit. The grey colour scale indicates increasing concentrations of geochemical elements from white to black. The medical parameters are presented by contour lines, the thickness of lines indicate increasing rate of events.



## *Žmogaus elgsenos pokyčiai bei somatiniai ir psichikos sutrikimai dėl geologinių veiksnių įtakos*

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### **SANTRAUKA**

*Žmogaus sveikatą veikia daugelis aplinkos veiksnių. Iki šiol labai mažai tyrinėta geoveiksnių įtaka žmogaus sveikatai. Analizuojamos keturios geoveiksnių grupės: a) gravitacijos ir magnetinių laukų, b) geocheminių elementų koncentracija dirvoje, c) tektoninė litologija, d) kraštovaizdis. Šios geoveiksnių grupės neapima visų galimų poveikių žmogaus organizmui, bet manoma, kad jų įtaka yra didžiausia. Tyrėme sutrikimus: tuberkuliozę, alkoholinę bei narkotinę priklausomybę, šizofreniją, taip pat savižudybes, nužudymus, nusikalstamumą. Skirtingi parametrai buvo lyginami pasitelkus GIS techniką, kuri leido 45 administraciniuose regionuose matematiškai analizuoti geologinius ir medicininius statistikos duomenis.*

*Nustatyta, kad šizofrenija teigiamai koreliavo su magnetiniais laukais. Gravitacinio lauko intensyvumas neigiamai koreliavo su nusikalstamumo lygiu. Tektoniniai lūžiai galėjo turėti įtakos savižudybių dažniui. Kraštovaizdžio įtaka nežymi. Reljefas galėjo turėti įtakos alkoholizmo paplitimui. Dirvožemio cheminiai elementai galėjo turėti įtakos atskiroms patologijoms vystytis: šizofrenijai ir savižudybėms įtakos galėjo turėti P-, Pb-, Sn-, Y-, Yb- elementų didesnės koncentracijos dirvožemyje. Tik vienas iš tirtų šešių patologijos atvejų – narkomanija – visai nepriklausė nuo geoveiksnių.*

*Geoveiksniai tarpusavyje glaudžiai susiję, todėl rasti koreliaciniai geologinių parametru ir žmogaus somatinių-psichikos bei elgsenos sutrikimų ryšiai rodo neabejotiną geoveiksnių įtaką žmogaus sveikatai.*

