Characterization of borehole water quality from a volcanic area for drinking. Case of the Menengai geothermal project boreholes, Kenya

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Abstract

Groundwater samples were collected from eight boreholes in Menengai geothermal field located within the East African Rift Valley. The main objective was to assess the suitability of the borehole water for drinking. Physical, chemical and toxicological parameters associated with volcanicity in the water were measured. Samples were assayed for trace elements; mercury (Hg), Cadmium,(Cd), Arsenic (As) and Lead(Pb) using an Atomic Absorption spectrophotometer (AAS) while soluble anions; nitrates (NO_3^-) ,chlorides (Cl^-), and fluorides(F^-) were analyzed on an Ion chromatograph (IC). Physical parameters were determined in-situ using a pH meter and a combined Total Dissolved Solids (TDS)-Electrical conductivity (EC) -Temperature meter. Measured results were related to the World Health Organization (WHO) and Kenya National Environmental Management Authority (NEMA) regulations for drinking water to assess suitability. Trace metal concentration was below detection limit except for As which ranged between 0.01-0.21 µg/l. All physical parameters were within the recommended limits indicating suitability for drinking except fluoride which had concentration above the WHO recommended 1.5 mg/l.

1. Introduction

The quality of groundwater is constantly changing in response to daily, seasonal and climatic factors. Continuous monitoring of water quality parameters is highly crucial as change in the quality of water has far reaching consequences on man and biota. A number of natural and anthropogenic factors influence water chemistry including geological processes, atmospheric pollution and agricultural practices. Pollution of water resources as a result of toxicity has become a source of concern among consumers due to far reaching impacts on human health and especially biological systems. The toxicity of various trace metals in water depends on their thresholds, which at certain levels is considered essential for biochemical processes. However, in extreme cases, high levels could bio-accumulate in living systems causing serious biological imbalances.

The cut-offs points between deficiency, normal health and toxicity, varies in different elements. Lead, though not considered to be as toxic as Mercury and Cadmium, is so wide spread in our consumer society and is probably the most serious toxic metal. Lead poisoning will affect the formation of blood cells in human beings and may result to anaemia and damage to the central nervous system leading to irreversible brain damage (Tyagi and Mehra, 1990). Arsenic has similar toxic properties to Lead and Mercury and Cadmium, as regards to bonding to sulfur and inhibiting enzyme action such as pyruvate dehydrogenase.

Large quantities of nitrate maybe consumed daily, but the reduction of nitrate to nitrite may produce toxic problems as nitrate is toxic to human beings, especially infants. It is necessary to control consumption, its deficiency can cause poor bones and teeth, while an excess shows up in the teeth (Tyagi and Mehra, 1990)

Menengai is a major quaternary central volcano dominated by trachytic lavas in the Rift Valley of Kenya. The age of the youngest eruption episode (~~1400 yrs.) indicates the possibility of a still active magma body below its Caldera (Mibei and Lagat, 2011). Detailed geothermal surface exploration was carried out in 2004, with subsequent infill exploration studies in 2009,2010, and 2011. This led to the first exploration well being sunk in 2011. The main objective of this paper is twofold; (i) to assess the levels of various physic-chemical parameters in drinking water, (ii), To find the suitability of borehole water for drinking by comparing to WHO and NEMA drinking water standards.

Ten (10**)** boreholes were drilled to a maximum depth of 220m supply water to the project The estimated productivity of each water borehole is 12m^3/hr, which is adequate for all drilling operation (GDC, 2008). One of these boreholes also supply water for domestic consumption to the nearby the local community.

The main objective of this paper is to describe the levels of various physic-chemical parameters associated with volcanicity in Menengai borehole water and assess suitability for human consumption and with the WHO and NEMA drinking water regulations

1.1 Location

The eight boreholes under study are located within the North eastern part of the Menengai Caldera (Fig: 1). The caldera is typified by a complex activity associated with the rift triple junction. This is the zone at which the failed rift arm of the Nyanzan rift joins main Kenyan (Mibei and Lagat, 2011).The boreholes are under the maintenance of GDC and thus the need for monitoring of trace elements especially associated with volcanology to guarantee suitability for human consumption.

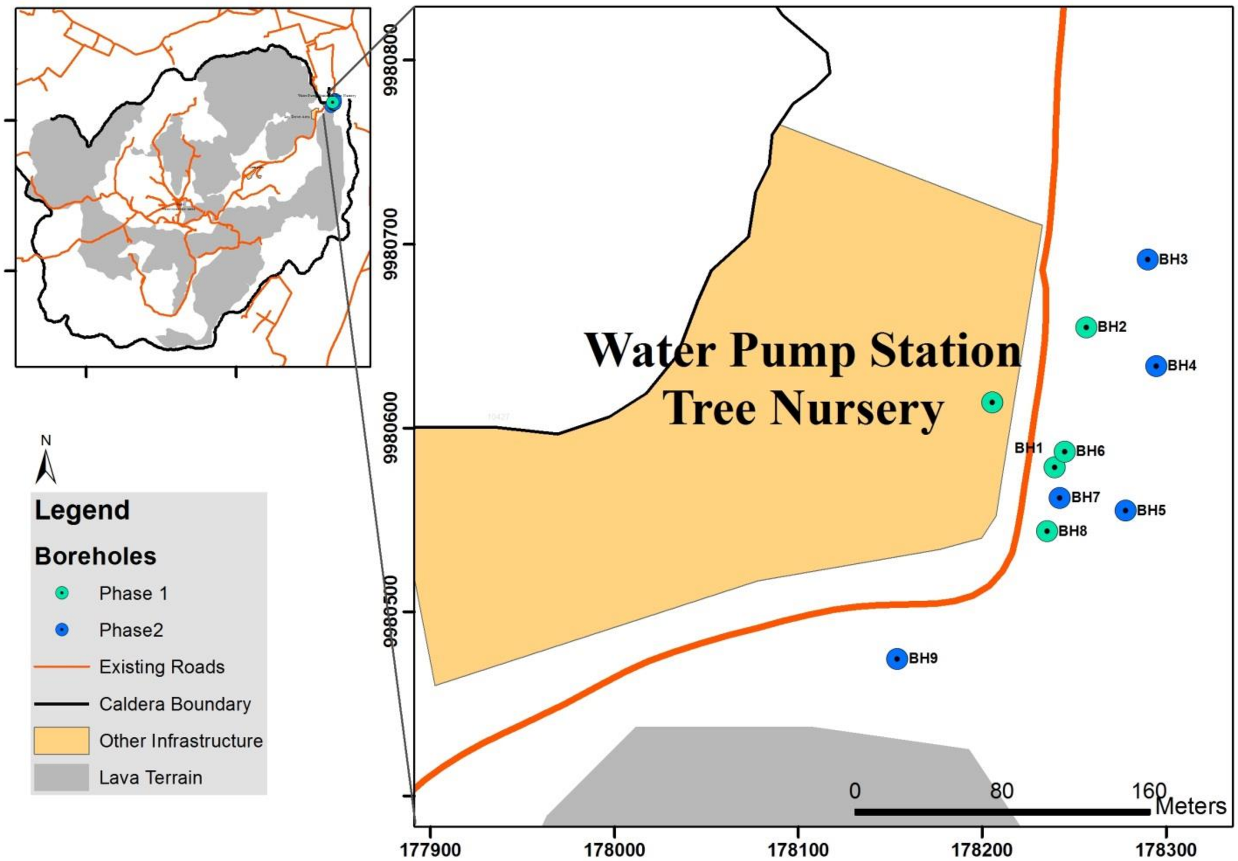

Fig 1 : Location of the Menengai boreholes

2.0 Methodology.

Groundwater samples were collected from eight (8) boreholes sites from January –May 2014, within the Menengai Caldera. Water from the boreholes was pumped for over 20minutes, before abstracting samples to avoid trapping foreign matter and for quality control.500ml Teflon sampling bottles pre-cleaned in 10% nitric acid were used to collect and store samples. All the sampling was done according to standard procedures where three replicates of water samples per borehole were collected (Hoda, 2010).

Filtration of the samples was done using a Sartorius polycarbonate filtering apparatus and a 0.45µm cellulose acetate filtering membrane to remove all suspended particles. Samples for trace elements (Hg, As, Cr, Cd,) elements were acidified to pH <2 with 1 mil/100ml of 10% analytical grade HNO3 to avoid both absorption and precipitation problems.

Samples were transported in ice cooler and stored at 4^{o}C to avoid microorganism action prior to analysis. Chemical analyses on the sample were conducted using standard procedures recommended by American public health association (APHA 2005). Trace elements were determined using an Atomic Absorption spectrometry. Analytical grade reagents were used for all the analysis and replicate measurements were done to ensure reproducibility and good quality control. Analysis of pH/TDS, /EC/Temperature was conducted on site using Jannway 3540 model pH meter. Cl,NO_3^- F^- were measured using single column IC Thermo scientific 5000 following protocols by American public health association (APHA, 1988).

All the recorded values were compared to NEMA standards and incase of no defined standards, WHO (2008) standards were used to suitability for drinking.

2.1 Data analysis

All data was described and analyzed using R. version 2.15.0 to check for differences between the boreholes sites in physic-chemical concentration, one way ANOVA was performed.

3.0 Results and discussion

3.1 Ground water quality and assessment for drinking

There was no significant difference between in physic-chemical concentrations between borehole sites ($p>0.01$)

3.1.1 Physical parameters

pH, Total dissolved solids; electrical conductivity and temperature were considered to be the main physical under this study. WHO, and NEMA drinking water guidelines recommend that pH values ranging from 6.5-8.5, at temperature between 19^{O}c-32.° C EC> 500µS/cm. Lower levels of TDS than 500mg/l indicates freshwater.

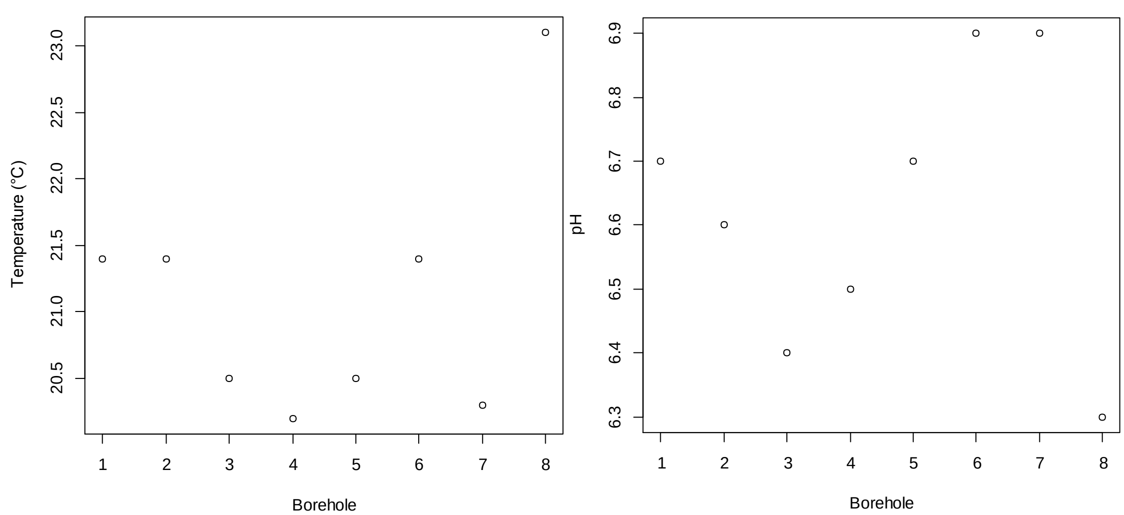

Fig 2. Temperature and pH plots of the monitored boreholes

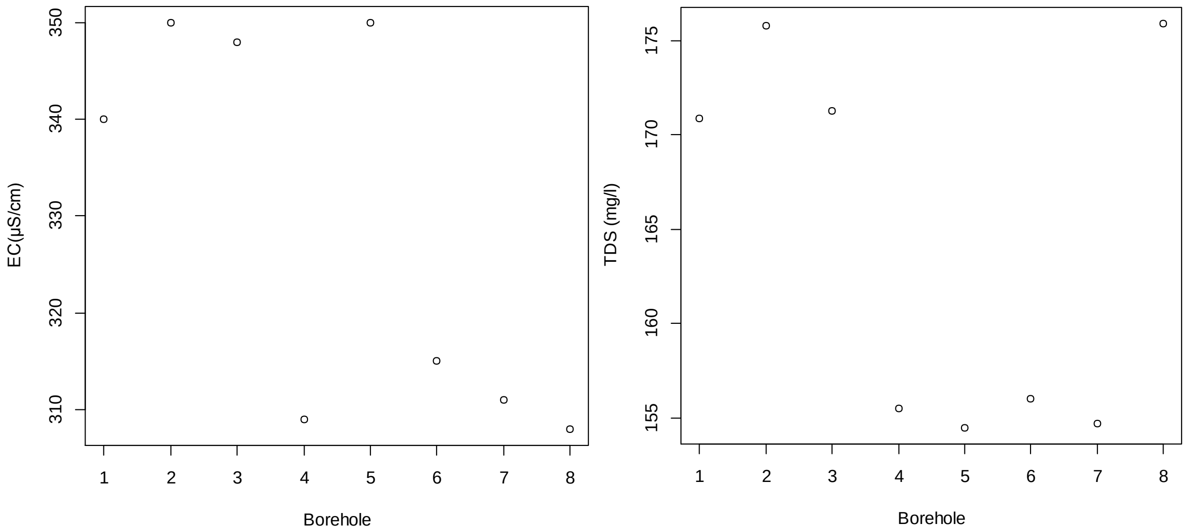

Fig 3: Electrical conductivity and total dissolved solids for the monitored boreholes

The minimum value of pH was 6.3 with a maximum of 6.9. This value was all within the accepted range of 6.5-8.5 of (NEMA and WHO) hence fit for human consumption. The acid limit values were recorded at a temperature of 27 °C on averages. pH values less than 6.5 are considered acidic for human consumption and can cause health problems as acidosis, while in excess of 8.5 can cause alkalinity and hardness problems .WHO recommends water with a temperature between 19-32^{O}C as ideal for human use. The electrical conductivity (EC) measured in µS/cm, recorded 305 and 350 µS/cm as minimum and maximum respectively. EC, states the amount of dissolved salts in water and it is a direct indicator of total dissolved salts or solids (TDS). WHO permits 500mg/l as maximum allowed for drinking water. From the results in this study based on pH, EC, Temp, and TDS, a recommendation is given for human consumption.

3.1.2 Chemical parameters

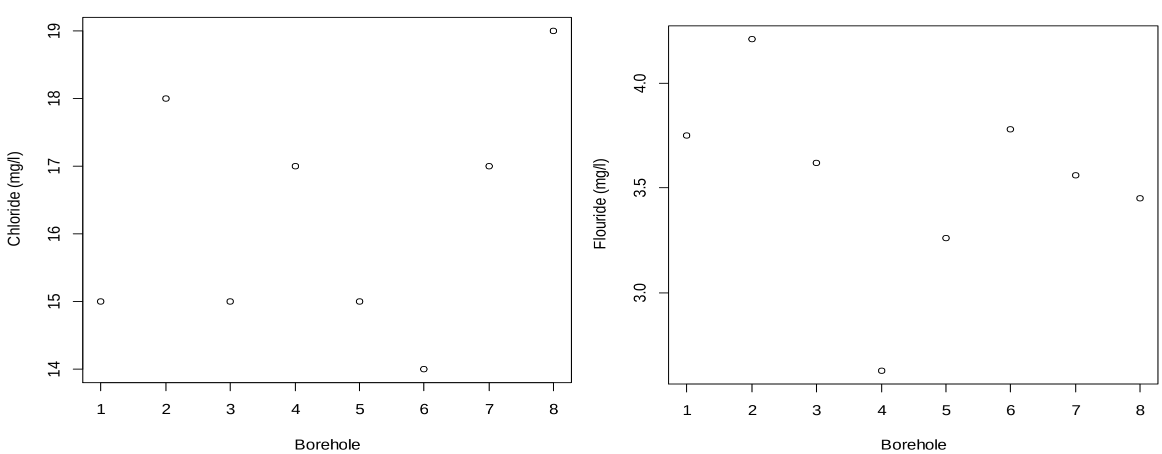

Fig 4: Chlorides and fluorides for the monitored boreholes

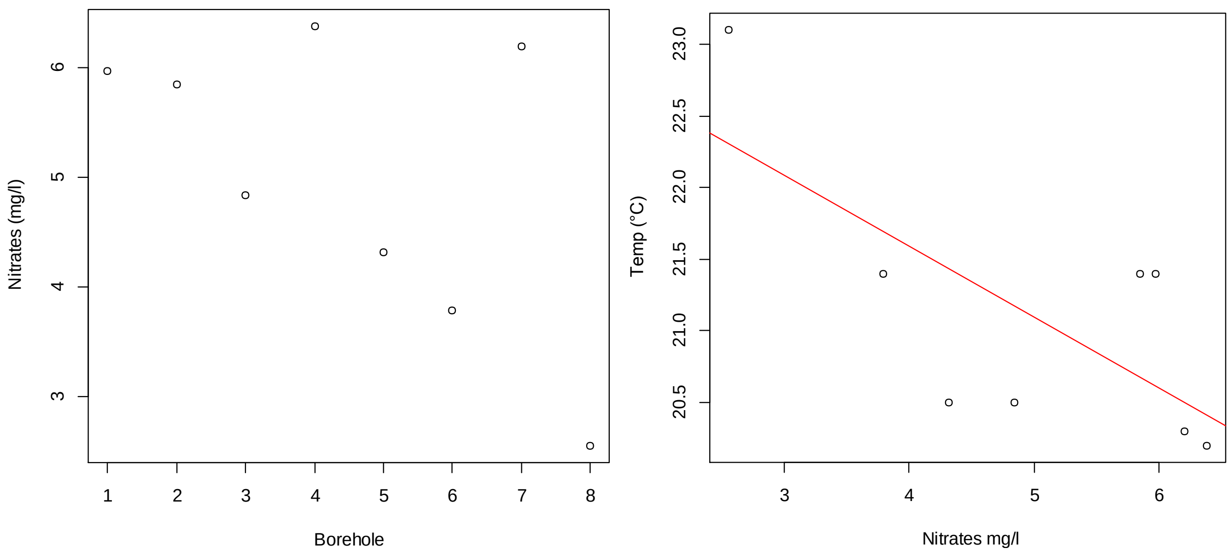

Fig 5: Nitrates and temperature for the monitored boreholes

Chlorides

Chloride ions were relatively low, with a minimum of 14 mg/l and a maximum of 19 mg/l . These were within the recommend falls standard of WHO 1996 recommends of 10-250mg/l Excess concentration of Cl, gives a salty taste and has a laxative effect on people not accustomed to it (WHO, 1996).

Nitrates (NO_3^-)

The concentration of Nitrate in drinking water should not exceed 10 mg/l (WHO 1996). Excessive (NO_3^-) can cause health disorders such as baby disease or Methemoglobinemia, goitre, and hypertension. (WHO, 1996) .In this study, majority of the samples measured a minimum of 2.56 mg/l and a maximum of 6.2 mg/l.

3.1.4 Fluoride (F-)

One of the essential elements for maintaining normal development to health teeth and bones is fluoride. Lower concentrations of F- below 0.6mg/l may contribute to dental caries. However, continuing consumption of higher concentrations above 1.5 mg/l may cause dental fluorosis and extreme cases even cause skeletal fluorosis. (WHO, 1996). This study however showed that fluoride levels in the boreholes were higher than the recommended standard of 1.5 mg/l. higher concentrations of up to 6 mg/l were observed.

3.1.5 Lead, (Pb) Arsenic (As), and Cadmium (Cd), Mercury (Hg)

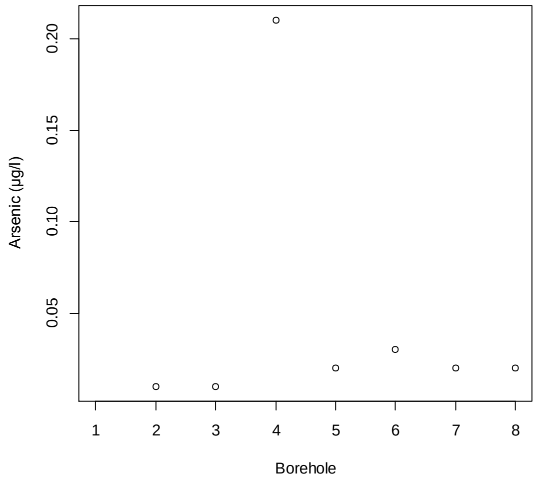

Fig 6: Arsenic concentration for the monitored boreholes.

According to the NEMA and WHO standards, the concentration of Hg, As, Pb and Cd should be 0.001mg /l ,0.05mg/l ,0.01mg/l and 0.003mg/l respectively (WHO, 1998).These element were measured because they do not have value to human diet and also, are associated with many health problems. Accordingly, the observed results shows that all the measured trace elements were within the WHO, and NEMA allowable standards. Hg was not detected in many samples and where it was measured, it was below 0.01µg/l. Similarly, Pb was not detected in the samples as opposed to As, which recorded concentrations from 0.01-0.21 µg/l which is within the accepted standard of 50µg/l.

4.0 Recommendations

From the results observed in this study, it was found that the borehole water from the Menengai Caldera is suitable for human consumption with defluoridation. However, more studies should be carried out for the rest of the parameters not considered in this work. Also, the future studies should consider exploring into the suitability of the water for use in irrigation. Additionally, bacteriological analysis is also highly recommended

5.0 Conclusion

Water samples from the Menengai boreholes were collected for physical and chemical investigation to establish its suitability for consumption. Both physical and chemical characterization on the borehole samples was done. The physical parameters considered were TDS, EC, pH and temperature as these are majorly known to affect the suitability of drinking to be fit for human consumption. pH measured was in the range of 6.3 -6.9, indicating that there was no acidification when measured against set standards of NEMA and WHO. The highest recorded specific conductance level was 350µS/cm which was within the set standard of 500 µS/cm. At the same time, all the trace elements determined included Hg, Cd, Pb, and As. Were within the NEMA and WHO accepted standards. These elements have no value to the human diet were within the set standards of WHO and NEMA as fit for drinking. However, this study was also able to point out that the concentration of Fluoride was beyond the recommended threshold of 1.5 mg/l hence this can cause problems associated by it. This therefore calls for action regarding on how the concentration of fluorides in the water would be dealt with to avoid the associated risks of fluorosis.

5.0 References

Ahamed A; 2013 a comparative evaluation of groundwater suitability for drinking and irrigation purposes in Pugalur, Karur district, Tamilnadu, India; achives of applied science Research 2013 :213-223

Brindha, K Elango, L. Hydrochemical characteristics of groundwater for domestic and irrigation purposes in Madhuranthakam, Tamil, Nadu, India; Earth sci. Res.SJ Vol.15, No.2 2011(101-108)

Ramesh. K, Elango E; groundwater quality and its suitability for domestic and agricultural use in Tondiar river basin, Tamil Nadu, India; EnviornMonit Assess(2231-3),2011

Ackah ,M .Agyemang O, Assessment of groundwater for drinking and irrigation: The case study of Triman-Oyarifacommunity,GaEast Municipality, Ghana; proceedings of international Academy of Ecology and Enviornmental sciences,2011 1(3-4):186-194

Mibei, G. Lagat. J; structural controls in Menengai geothermal field;proceedings, Kenya Geothermal congress 2011

Mibei G.;Geology and hydrothermal alteration of Menegai Geothermal field; United Nations University- Geothermal training programme Report 21, 2012

Mohsen,B suitability assessment of deep groundwater for drinking and irrigation use in the Djeffara aquifers (Northern Gabes south-eastern Tunisia;openaccesss at Springerlink.com Environmental earth science 2013

Mona A. ; Water quality assessment and hydrothermal characteristics of groundwater in Punjab, Pakistan; IJRRAS 16(2) 2013; www. Airspace.com, vol 16 issue2

Venkateswaran, S, .Vediappan S; Assessment of groundwater quality for irrigation use and evaluate the feasibility zones through Geospatial Technology in lower Bhavani Sub Basin, Caivery river, Tamil Nadu, India;Internationla journal of innovative Technology and exploring engineering (IJITEE) ISSN :2278-3075, Vol-3, issue-2 2013

Sudhakar A. and Narsimba A.; suitability and assessment of groundwater for irrigation purpose: Acase study of Kushaiguda area, Ranga Reddy district, Andhra Pradesh, India; advances in applied reaserch, 2013,4(6): 75-81

Taha H, Salim A; groundwater quality of areas selected NE of Mousl City used for irrigation and drinking purposes; Al-Rafidain Engineering Vol.17 No.3 2009

GDC; 2008. Environmental impact assessment study report, Menengai Geothermal drilling project, Nakuru;