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BATTERY RECYCLING TECHNOLOGY

Russian market research

Thesis
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ABSTRACT

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The thesis is made for Rec Alkaline Oy, a company located in Nivala and having production facility in Kärsämäki. The purpose of this thesis is to give a description of battery recycling technology with final product in agriculture – micronutrient fertilizer. Explanation of the fertilizer's role in farming and food industry. The thesis is made referring to Russian market and includes market research for Saint Petersburg area and results of practical progress in finding business partners and investors.

The market research is based on secondary data from public sources and the company's documents from previous studies of the region. Quantitative approach was selected due to availability of statistics and specialization of the industry.

Conclusion is a general overview of technology and its feasibility in the Russian market.

A significant amount of information is taken away by request of Rec Alkaline's Chief Executive Officer. All Abstracts and paragraphs of text which were deleted are now marked as **CLASSIFIED.**

Key words
Alkaline battery, Leningrad region, market research, micronutrient fertilizer, recycling, Saint Petersburg

CONCEPT DEFINITIONS

CIS - Commonwealth of Independent States, former Soviet Union countries

DNA - deoxyribonucleic acid, a self-replicating material which is present in nearly all living organisms as the main constituent of chromosomes. It is the carrier of genetic information.

ELY-KESKUS - Centre for Economic Development, Transport and the Environment

NPK -fertilizer containing nitrogen, phosphorous and potassium

RBRC - Rechargeable Battery Recycling Corporation

RNA - ribonucleic acid, a nucleic acid present in all living cells. Its principal role is to act as a messenger carrying instructions from DNA for controlling the synthesis of proteins, although in some viruses RNA rather than DNA carries the genetic information.

TEKES - Finnish Funding Agency for Innovation

ZMS - Zinc and manganese sulphate

ABSTRACT
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1 INTRODUCTION

The background of my thesis is so vast that it is hard to cover, but in short I am going to demonstrate the unique technology aimed at saving our planet and millions of lives. Thesis is limited within borders of Finland, home of new technology, and Russia – my motherland and one of the biggest markets.

Since the beginning of human civilization, there have always been people suffering from food hunger. It is inevitable due to poverty, social inequality and, especially, food shortage. The situation got worse with technological progress, reduction of arable lands and overpopulation. What is more, useful and healthy elements are less concentrated in modern vegetables and crops due to incorrect cultivation and fertilization.

Another major problem of the world we live in – overloaded landfills of batteries which poison our earth - because chemicals leak out of corroded shells, water - because those dangerous elements find ways into ocean and rivers, air - because lithium tends to burn and set up huge areas of wastelands on fire.

Rec Alkaline has found a unique solution for both problems and I am going to describe it in my thesis. Report will also include full description of final product, its ingredients and efficiency. My own objective here is to write a good piece of work which can be also used in promotion of Rec Alkaline company in the future, to study the fertilizer market, competitors and product's potential. Russian market can be very difficult to enter due to cultural difference, other values, trade policy issues and high risk of investment. However, if finding right partners and promoting product efficiently, Russia can be one of the most profitable markets for cheap fertilizer with 55 times more arable lands than in Finland. Amount of practical work done related to business expansion is another valuable experience which I will reflect in thesis too.

2 THEORETICAL KNOWLEDGE

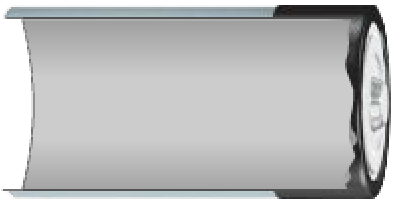
2.1 Content and working principle of alkaline battery

Alkaline batteries in modern world are necessary as portable energy resources and appear to be a vital part of many devices. Batteries are used where energy supply is unequal or problematic, also many small devices like watches, cameras and mobile phones need lower voltage than in the electricity network. Another cause of battery popularity is its capability of saving and transporting energy if there is no electricity network or when power supply drops.

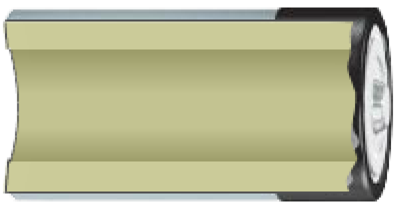
All types of batteries contain electrolysis – main element allowing current to flow through the specific mixture. Electrolysis is used for other purposes too, such as overcoming the weight and mechanical weakness of lead plates. The reason why alkaline battery produces energy lies in chemical reaction between zinc (Zn) and manganese dioxide (MnO2). This type of battery is named alkaline because potassium hydroxide, the electrolyte, is a pure alkaline substance.

How is it technologically possible to store energy in such small devices? Let’s see what an alkaline battery consists of:

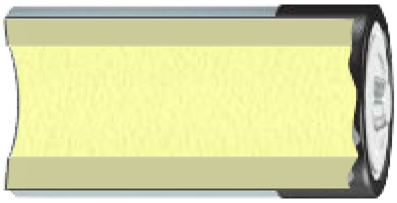
1. Container made of steel serving as shell to form cathode for electrochemical reaction



2. Cathode is a mixture of carbon, manganese dioxide and conductors carrying a natural electric charge. Cathodes are the electrodes reduced by the electrochemical reaction. Cathode mix is attached to inside wall of steel container

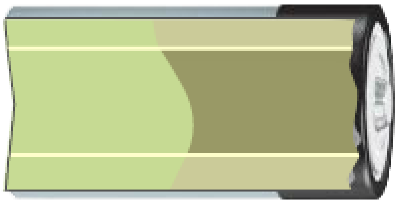


3. Separator is a non-woven, fibrous fabric that keeps cathode from touching anode

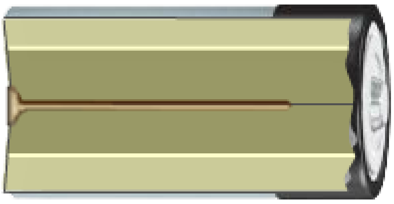


4. Anodes are oxidized electrodes, where chemical reactions are going on. Anode is a powered zinc metal. It carries negative electric charge and along with electrolyte is pumped into different containers

5. Electrolyte is a potassium hydroxide solution in water. It is a medium for the movement of ions within the cell and carries the iconic current inside the battery.

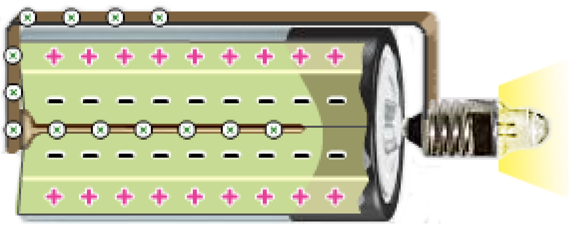


6. Collector is a composition metal pin in the middle of the cell which leads electricity to the outside circuit. It forms negative current and is last part installed before sealing the battery.

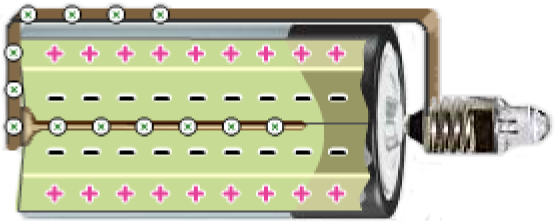


How does a battery produce electricity?

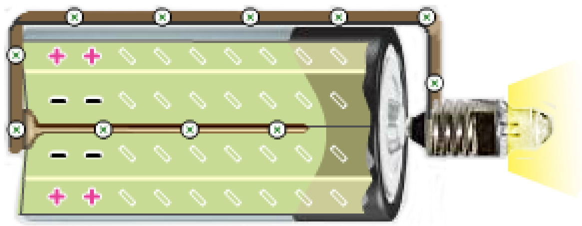
1. When battery is inserted into device circuit becomes complete and chemical reaction starts



2. Device responds when electrolyte oxides the anode’s zinc. Mix of carbon and manganese dioxide in cathode starts to react with oxidized zinc in order to produce energy



3. Interaction between zinc and electrolyte produces reaction products. As a result, cell’s action slows down and voltage drops.



(Energizer. How do batteries work.)

2.2 Alkaline battery environmental impact

It is estimated that one alkaline battery, carelessly thrown in the trash, can contaminate with heavy metals about 20 square meters of land, what equals in an average forest to the territory inhabited by two trees, two moles, a hedgehog and several thousand earthworms! (Used batteries - dangers, where to send and why they are not recycled in Russia?, 2013.)

The battery contains a variety of different metals - mercury, nickel, cadmium, lead, lithium, manganese, and zinc, which tend to accumulate in living organisms (including the human body) and cause significant harm to health. (About harm of batteries, 2015; Usmanova, 2014)

Many battery chemicals are corrosive, poisonous or both. If leakage occurs, either spontaneously or through accident, the chemicals released may be dangerous. For example, disposable batteries often use a zinc "can" both as a reactant and as the container to hold the other reagents. If this kind of battery is over-discharged, the reagents can emerge through the cardboard and plastic that form the remainder of the container. The active chemical leakage can then damage or disable the equipment that the batteries power. For this reason, many electronic device manufacturers recommend removing the batteries from devices that will not be used for extended periods of time. (Adkins, 2011; Malavika, 2004.)

2.3 Response of governments and environmental organizations

In 1996, a law was passed to lower mercury level in alkaline batteries and many countries accepted disposal of such batteries as domestic trash, however European Union and California state still consider all batteries as dangerous for environment. The Battery Directive of the European Union has similar requirements, in addition to requiring increased recycling of batteries and promoting research on improved battery recycling methods. This European Commission Directive 2006/66 also sets impressive goal - 25% of batteries have to be collected by 2012 and 45% by 2016. The aim of EU directives is to develop EU's circular economy, where the goal is to prepare the materials and products in such a way that they remain in circulation. Developing the circular economy requires changes in the entire value chain, from product design to new business and marketing models, as well as consumer behavior. The ultimate aim is to minimize the use of materials that cannot be recycled. Finland is committed to significant reduction of carbon emissions over the next decades. The Directive has been implemented in Finland by Government Decree (520/2014) on batteries and accumulators. Commission Regulation (1103/2010) for portable secondary batteries**,** automotive batteries and accumulators came into force on 30.11.2010. The Regulation applies in the Member States as such, and its requirements for rechargeable batteries**,** automotive batteries and accumulators have affected the market since 31.5.2012.

For example, in Finland battery manufacturer association is responsible for collecting all types of batteries and alkaline ones take about 80% of this amount. Also, shops are obliged to have battery receiving boxes which are later sent to recycling facilities. Alkaline batteries contain high quantity of zinc and manganese which can be reused in many ways. Extracting those elements has always been problematic and energy-intensive, but with the appearance of Rec Alkaline technology, the problem has been overcome. Other companies are also making efforts since global alkaline recycling goal jumps from 4% in 2015 to 40% in 2025.

In North America, Retriev Technologies, formerly Toxco, and the Rechargeable Battery Recycling Corporation (RBRC) collect spent batteries for recycling procedure. While Retriev has its own recycling facilities, RBRC is in charge of collecting batteries and sending them to recycling organizations. Retriev claims to be the only company in the world to recycle big lithium accumulators, however they have

invented their own technologies to recycle nickel-cadmium, nickel-metal-hydride, lead, mercury and others.
Europe and Asia are also active in recycling spent batteries. Among other recycling companies, Sony and Sumitomo Metal in Japan and Umicore in Belgium have developed technology to retrieve cobalt and other precious metals from spent lithium ion batteries. Also the BEFESA smelting plant in Germany is recycling various batteries to extract Zinc, but other waste goes to landfills and overall recycling efficiency stays around 50%. (Battery University, 2015.)

In Finland Recser Oy is responsible for battery collection having 16 000 receiving points across the country in shops, factories and offices. Recser Oy is a producer organization for businesses placing portable batteries and accumulators on the Finnish market. According to Finnish legislation a producer is liable for collection and recycling of batteries and accumulators placed on the market by the producer. Companies producing portable batteries and accumulators can manage their statutory producer responsibility by concluding a producer liability transfer agreement with Recser Oy. Recser Oy manages recycling, publicity, registration, and other statutory obligations on behalf of the producer who signed the agreement. **CLASSIFIED**

2.4 Basic battery recycling procedure

The average battery recycling process starts with sorting. Lead acid, nickel-cadmium, alkaline and lithium ion must be put into different containers. Companies focused on battery recycling claim the process is profitable if steady flow of sorted batteries is assured.

First step after batteries are sorted out – removal of packaging like plastic, papers and isolation materials. Those parts are being burned and released in the atmosphere after environmental threat is avoided by gas purification system. As a result, we get clean alkaline battery content with metal shell.

Next move requires crushing batteries into small pieces and high temperature melting of metal. Other substances get burned and removed by slag arm. Cadmium is a rather light element and evaporates at such temperature. A special ventilator directs the cadmium vapes in tubes where it is cooled down with water haze, what allows high recycling efficiency with 99,95% cadmium purity rate.

Some recycling companies do not bother to separate metal and fill large containers with liquid metals. The batches are sent to metal recovery plants where nickel, iron and chromium are extracted. To lower risks of explosive reactions during crushing many recyclers use liquid nitrogen cooling down lithium batteries, however li-ion charged batteries may still cause unfortunate situations at recycling site.

One of the main drawbacks of traditional recycling method is the high energy consumption, going up 10 times more than metal extraction using mining. Exceptions are extraction of lead and nickel where the process is economically viable considering larger volumes.

Every country has their own regulations in making recycling profitable what mainly results in additional fee while purchasing new battery. USA has a recycling division by weight and battery type. While nickel has high value after recycling procedure, cadmium market prices fluctuate and lead to lower NiCd used battery demand. Also Li-ion batteries require bigger recycling fee because of lower metal extraction value. Average U.S. recycling cost per ton of batteries varies from 1000 to 2000 dollars, while Europe is aiming at cost reduction down to 300 dollars. EU hopes to include all transportation costs in this price but it could also double the cost due to complicity of the process. Construction of smaller recycling facilities across Europe will lower the costs and help to overcome Basel Convention which bans export of used lead acid batteries. As volumes of batteries and recycling demand increase globally, many manufacturers are seeking more efficient recycling methods apart from government projects. (Battery University, 2015.)

Paragraphs 2.5 and 2.6 are **CLASSIFIED**

3 NUTRIENTS IN NATURE

Let's start with the basics of agriculture to understand the significance of the technology. In general, 16 chemical elements have been proven to have positive effect on the way plant grows and resists diseases. Those elements are separated into 2 large groups: non-mineral and mineral.

3.1 Non-mineral nutrients

These include hydrogen, oxygen and carbon. The elements are widespread in the air and water
There are 13 mineral nutrients coming from soil and consumed by plants with water. Main principle of plant's self-support is photosynthesis, what allows them to receive energy from sun in order to change carbon dioxide (carbon and oxygen) and water (hydrogen and oxygen) into starches and sugars which are main sources of plant's food. Because those non-mineral nutrients are received by plant through air and water, farmers can only maintain irrigation at sufficient level in order to help plants get their natural nutrient supply. (Wikipedia, Plant nutrition; Grigorovskaya, 2013.)

3.2 Mineral nutrients

13 types of elements are located in the ground in uneven amount and represent the second source of plant's nutrition resource. Usually some of the elements are missing due to nature of soil, weather conditions or harm done by humans during inappropriate agricultural treatment. However, farmers can fix the situation and deliver necessary elements through usage of fertilizers. Mineral nutrients can be divided into 2 groups: macro and micronutrients.

TABLE 6. Macro- and Micronutrients (own source)

Macronutrients	**Micronutrients**
Nitrogen (N)	Boron (B)
Phosphorus (P)	Copper (Cu)
Potassium (K)	Iron (Fe)
Calcium (Ca)	Chloride (Cl)
Magnesium (Mg)	Manganese (Mn)
Sulphur (S)	Molybdenum (Mo)
	Zinc (Zn)

CLASSIFIED

Some of nutrients mentioned in TABLE 6 are not available to plants due to unfavorable types of soil. The acidity (pH) and soil structure can affect the access of nutrients into the plant roots. The main soil-forming rocks are clay, loam, sand and peat. Imbalance of components leads to leaching of the soil, which decreases nutrition of plants. In general, plants do not need big amounts of micronutrients, but their lack can significantly limit height and yield of various types of plants. Advanced testing technology in recent years played a major role in understanding how important it is to add micronutrients to the arable lands. Turned out there is significant deficiency of zinc and manganese in soils and constant usage of NPK fertilizers make it worse – even natural micronutrients are flowing away from soils which results to low productivity and eutrophication (chemical pollution) of nearby rivers and lakes, eventually turning the landscape to swamps and dead fields. Researchers worldwide had admitted the crucial role of micronutrients in the development of major crops, how they nourish and strengthen the plants and organically combine with complex fertilizers. (Khan, 2014.)

3.2.1 Macronutrients

Macronutrients can be divided into primary and secondary elements. First group includes Nitrogen, Phosphorous and Potassium. The most common fertilizer is called NPK because it represents 3 elements by their chemical signs. Plants are use large amounts of those elements in order to survive, that's why it is common situation of lack of those elements in the fields. Macronutrients level in plants is normal in range of 0.2% and 4% based on dry matter weight. Farmers must be very careful with dosage of such fertilizer because exceeding the norm will result in burns of leaves and eventual death of the plant. Plenty of research has been done during modern history of agriculture describing negative impact of nutrient overdose on humans caused by consumption of fruits and vegetables with excessive content of macro-nutrients. Another problem appears after few agricultural seasons, as continuous addition of NPK fertilizers washes away natural elements of soil, especially micronutrients, causes eutrophication – pollution of nearby water reservoirs such as rivers and lakes and reduces plant's ability to grow. If TraceMix (or any other compound micronutrient fertilizer) is added along with NPK fertilizer those problems minimize or even disappear. Since my thesis topic is related to Rec Alkaline company and its fertilizer product, I will describe nutrients it contains in a more detailed way compared to elements missing in the ingredient list. In brief, nitrogen is a core element affecting plants growth, has the fastest and most obvious visual effect. Important to remember, that overdose of nitrogen results in low quality of fruits, crops and vegetables, slow growth and low winter resistance. This element can easily be washed away from the soil therefore it is applied in early spring before seeding. Phosphorous has great effect on early growth of plant and development of its root system. When balanced with other nutrients, phosphorous speeds up the reproduction phase of a plant and increases sustainability of plants to cold weather or drought. Farmers and gardeners have to keep in mind that adding too much of this element will lead to zinc deficiency, which has crucial meaning on health of plants, soil and consumers –our mankind. (Wikipedia. Plant nutrition; Sadurad, Plant nutrition and fertilizers.)

3.2.1.1 Potassium

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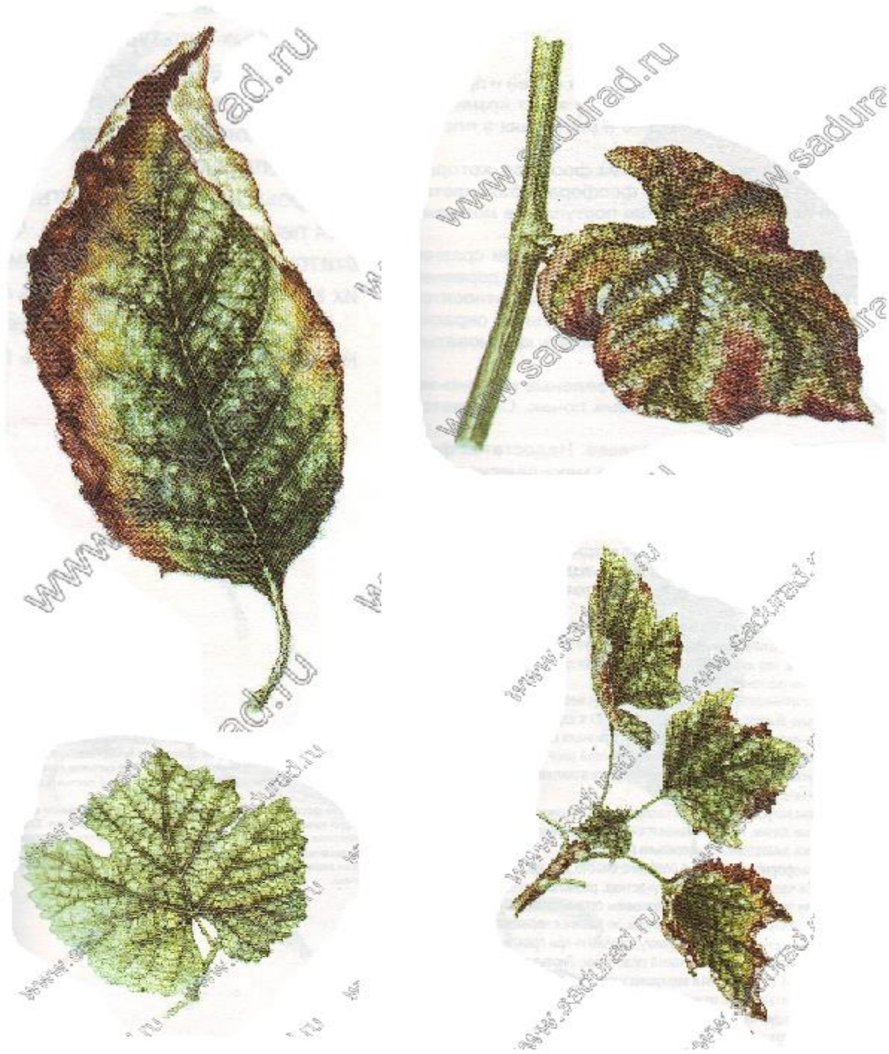
It is main element helping a plant to resist various stress conditions, such as surplus and lack of humidity, high and low temperatures, high concentration of salts. It contributes to a better maturation and stronger root's winter hardiness, increases resistance to fungal and bacterial diseases, improves crop quality and increases its keeping capacity. Potassium has the highest mobility and solubility inside the plant's system, it is involved in the process of formation of carbohydrates and proteins. This macronutrient also plays a role of accelerator of enzyme reaction and benefactor to photosynthesis, helping plant to receive non-mineral nutrients even if sun light is rare and weak.

Potassium deficiency is the main reason of necrosis and interveinal chlorosis. Its lack inside the plant leads to higher risks of pathogens, brown spots and damage by frost or heat. Potassium deficiency symptoms begin to appear with the blanching or fading blue-green color of leaves. The edges of the leaves tend to fall down. Dried up border tissue appears along the edges of the leaf, what is called among the farmers as the edge "burn." What is more, lack of potassium results in uneven growth of leaf blades and shriveled leaves. The plant becomes stunted with short internodes, sprouts grow thin.

The symptoms of potassium deficiency are evident in the highly acidic soils and in places where excessive doses of calcium and magnesium have been applied. Potassium deficiency can be accompanied by deformation and leaf curl. Perennials and fruit plants on soils tend to lose their hardiness. Slight potassium deficiency leads to appearance of unusually large number of small buds on the trees, the tree is covered with flowers, but the fruits aren't developing to their normal sizes. Leaves of black currant with a detected lack of potassium can be purple with edge burns. Picture 4 below illustrates how Potassium deficiency actually looks like on the leaves.



PICTURE 4. Lack of Potassium on the plants (Symptoms of macro- and micronutrients deficiency in plant nutrition, 2016)

Secondary group of macronutrients is represented by calcium, magnesium and sulphur. Most of fertilizers on the market do not include secondary macronutrients because it is thought soil has enough of those elements before any treatment. In addition, Magnesium and Calcium are incoming in large quantities during lime application which is done in order to balance soil acidity. Sulphur is contained in decomposed soil organic matter, which is why farmers do not throw out grass cuttings and old leaves. **CLASSIFIED** (Sadurad. Symptoms of macro- and micronutrients deficiency in plant nutrition.)

3.2.1.2 Sulphur

Sulphur - is widespread in nature, an element that is essential for the functioning of both plant and animal organisms. It accumulates in the volcanically active regions, and there are large deposits of elemental sulphur in the world. Until relatively recent times, the raw material was volcanic sulfur and pyrite. In the 20th century G. Frasch developed new sulphur extraction method by melting its underground deposits, which expanded the use of sulphur in agriculture and industry.

Hydrocarbon minerals contain sulphur as it is included in the composition of organic compounds from which these minerals are formed. The sulphur is recovered as a byproduct of fossil fuels such as oil, gas and coal. Purification of fossil fuels decreases the sulphur emissions in the air what is crucial for environment. Currently, the elemental sulphur is obtained in the processing and refining of oil and gas. Sulphur is supplied to the world market in a solid or molten form.

Sulphur is an important product for the chemical industry, especially in the form of sulfuric acid. Industry producing fertilizers is the largest consumer of sulphur. Global supply and price of the element is closely connected with the market of fertilizers.

In soil, the sulphur is mainly composed of organic compounds represented by humus and plant leftovers. Sulphur is available to plants only in sulfate form – this form can be achieved in the mineralization process of organic compounds which involves microorganisms. The process of mineralization of soil organic matter and release of sulphur is often too slow to meet the demand of high-yielding types of crops. The resulting lack of sulfur should be eliminated by application of organic and mineral fertilizers containing sulphur, such as TraceMix.

Sulphur loss from the soil mainly occur due to leaching of sulfate ions from the root area due to large amount of rainfall and irrigation. Scale of sulphur losses from leaching depends on soil and climatic conditions - annual losses typically range from 5 to 60 kg of sulphur per hectare.

Disposition of sulphur during crop harvesting without adequate compensation through application of fertilizers gradually leads to the extinction of Sulphur from soil reserves. The use of sulphur-containing fertilizers may not be needed in soils with high organic matter, but the responsiveness of crops to the systematic application of sulphur-containing fertilizers is observed in many types of soil.

In general, sulphur has a great importance for plant's ability to produce proteins, develop vitamins, form chlorophyll, improve root growth and seed cultivation. Like potassium, sulphur helps plant to resist cold weather, fight plant pests and diseases. (Mikkelsen, Norton, 2014.)

3.2.2 Micronutrients

In this section I will shortly describe micronutrients which are not included into TraceMix material but still have value as a nutrition for various plants. Molybdenum is a rather significant element which has an important role in providing vital activity for plants, especially beans. It is part of the nitrate reductase enzyme, and is closely linked to the recovery of nitrates in plants. Molybdenum is a part of the few plant proteins. It concentrates in the growing, young organisms. Its highest amount is contained in beans, and in its concentration is higher in leaves rather than in roots and stems. Molybdenum concentrates in the composition of chloroplasts in the leaves. It is found that the root nodules contain several times more molybdenum than the leaf tissue. Molybdenum - an important component of nitrogenase and nitrate reductase. These two molybdenum enzymes are directly involved in nitrogen metabolism, playing a major role both in its fixation and in recovery of nitric oxide. Plant's necessity of molybdenum is directly related to providing them with nitrogen. Molybdenum is also present in other enzymes (oxidases) that accelerate diverse, unrelated reactions. The main enzyme role of molybdenum is directly related to the function of transferring electrons. Molybdenum, like iron, is necessary for synthesis of leghemoglobin (protein - transporter of oxygen inside the nodules). Its deficiency leads to a change of color of nodules to yellow or gray (normal color is red). (Grigorovskaya, 2013)

Boron is one of the rarest and most important plant micronutrients, although not required by animals or mushrooms. In plants, boron may be in the free form and in the form of complexes with organic compounds. Boron in its physiological role is different from other micronutrients: boron anions have not been identified as a component of any specific enzyme. It does not refer to the structural components nor activators of enzymes.

Boron functions are related to the following processes:

- Metabolism of carbohydrates and transfer of sugars through the membrane
- Synthesis of nucleic acids (DNA and RNA) and phytohormones
- The formation of cell walls
- The development of tissues (Scientists assume it is a part of transfer agent)

- Growth regulation
- Breathing of plant

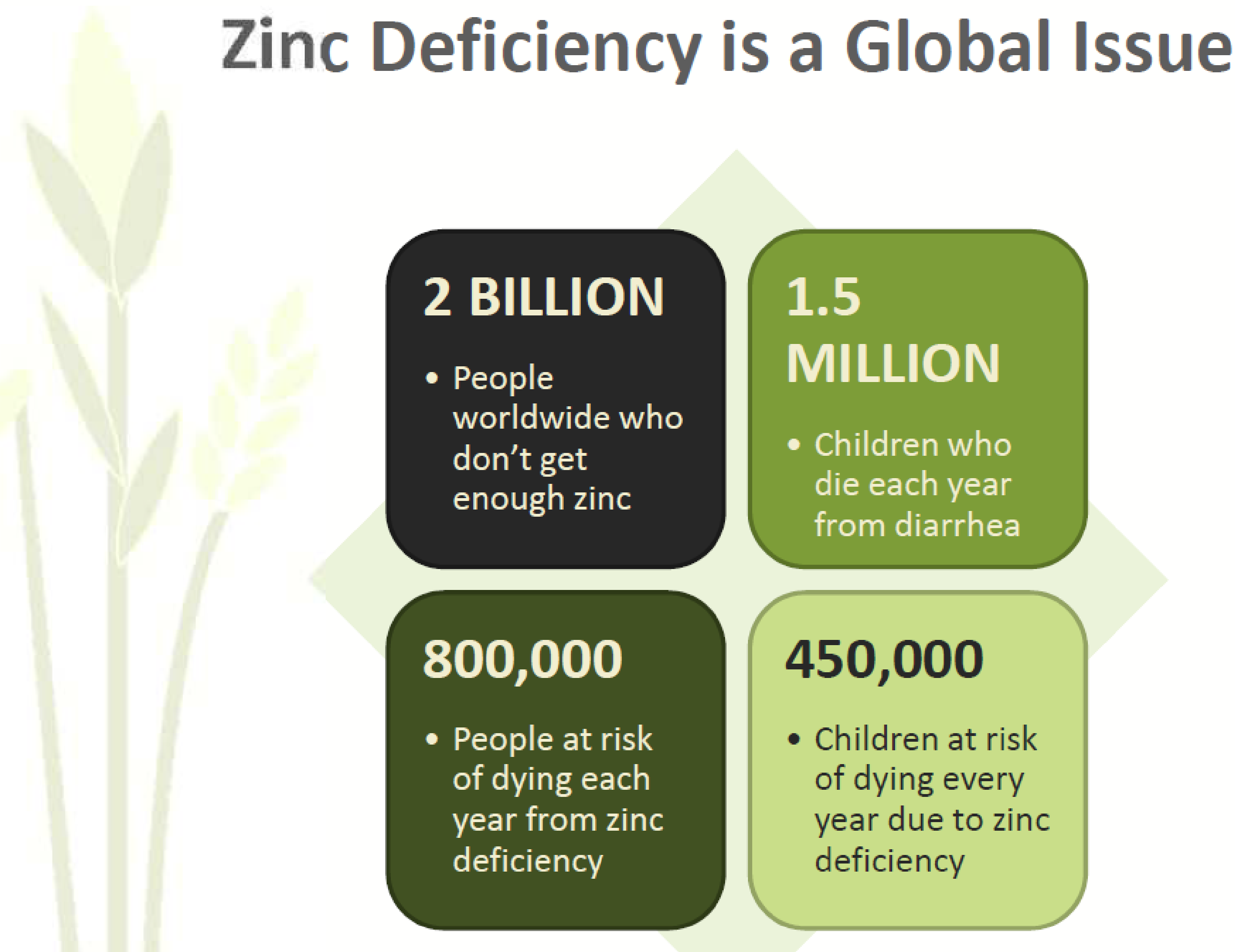
Main symptom of boron deficiency shows up when plant buds die out. Internodes become shorter, plants acquire signs of bushiness. Typical signs of a lack of boron - falling of flowers and buds, slower formation of the fruits, thinner plant cell walls. (Sadurad. Symptoms of macro- and micronutrients deficiency in plant nutrition.)

Chloride is another valid micronutrient which is required in very small amounts. Its main functions are:

- Participation in moisture level regulation in plants
- Activation of enzymes and chemical breakdown of water
- Support of manganese, potassium and calcium transportation within roots

3.2.2.1 Zinc

Zinc is most likely the first micronutrient scientifically proven to have significant impact on a plant's growth, health and harvest weight. As any micronutrient, it is required only in small dosage but turned out to be key element affecting yield. Zinc has many applications associated with the growth of the plants: the formation of proteins, gene regulation, protecting the cells from oxygen free radicals. Zinc is involved in the formation of carbohydrates and plays an important role in the production of growth hormone auxin and regulates plant growth. What is more, zinc regulates consumption of sugar and is vital for human body as well.



PICTURE 5. Zinc deficiency as a global issue (International Zinc Association, 2016)

Zinc is a very important nutrient which affects millions of human lives, the problem is especially serious in Asia, where two thirds of the rice plantations suffer from the lack of Zinc. Its deficiency raises more concerns because it is estimated that the overall rice production must increase by 25% in the next 20 years to keep up with the demand of growing population. Today rice is a source of 80% of calories for 3 billion people in Asia alone. For higher productivity crop nutrition balance must be maintained. One of the researches illustrated in Table 7 shows significant reduction in yield due to low amount of zinc in the soil.

TABLE 7. Harvest of rice dependent on level of Zinc (Zinc in Soils and Crop Nutrition, 2008)

Country	+Zn (t/ha)	-Zn (t/ha)	% Change
Columbia	9.3	7.5	-19%
	11.3	10.3	-8%
	12.0	9.8	-18%
China	8.2	7.3	-10%
India	9.95	8.7	-12%

There are several reasons for Zinc deficiency in soil:

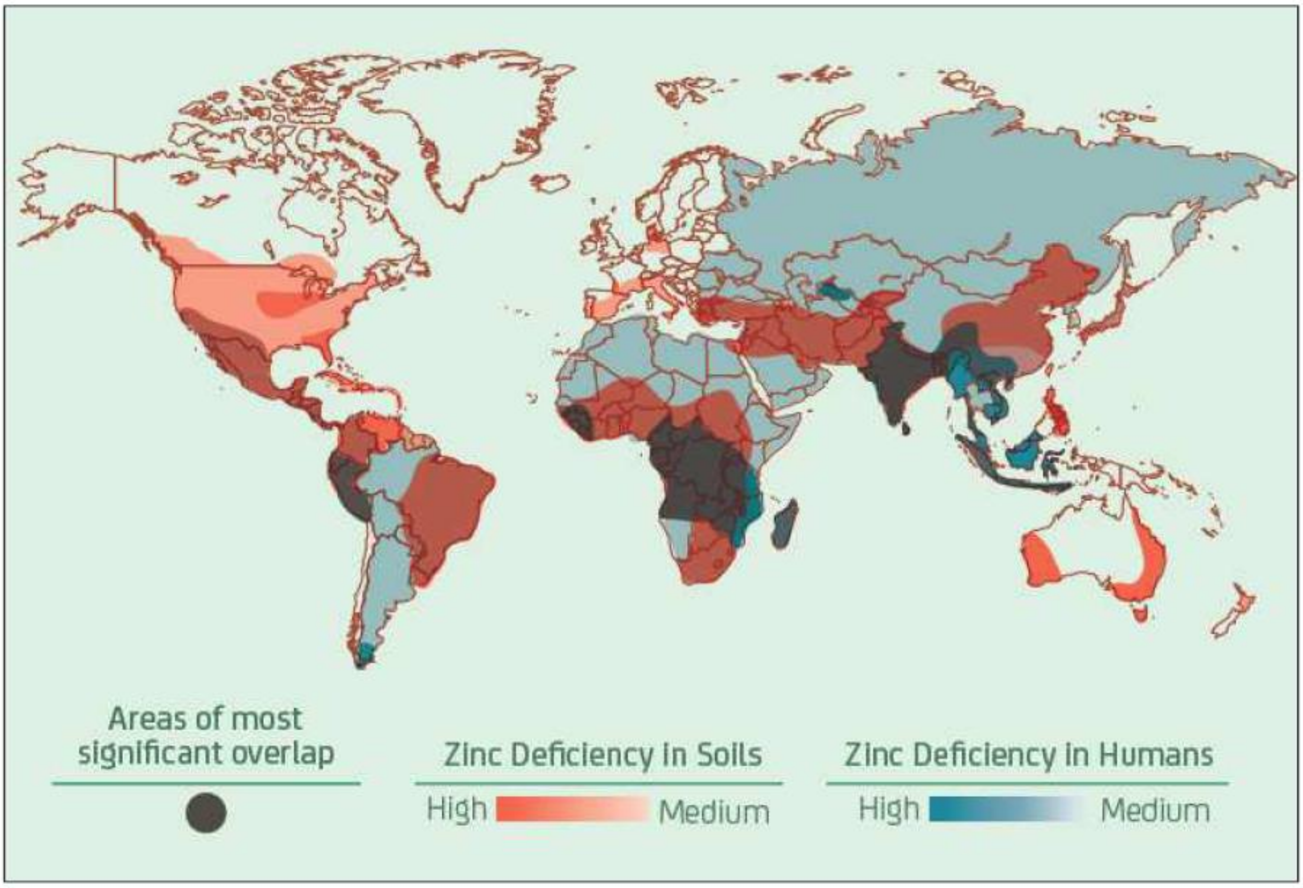
1. Neutral and calcareous types of soil with low level of zinc and sulphur which, for example, cover vast areas of India, China and Bangladesh
2. Intensive fertilization with basic NPK fertilizers over several years
3. Rice fields with crops growing 3 times a year and long inundation (water flooded)
4. Soil type with high availability of phosphorus

Zinc deficiency in crops directly affects its level in humans, therefore maintaining zinc level at appropriate figures will solve social, economic, health and hunger problems globally. Humanity cannot ignore this issue much longer as the World Health Organization ranked zinc deficiency as the fifth reason of deaths and diseases in developing countries. (Zinc Nutrient Initiative and The International Rice Research Institute, 2016.)

Apart from vegetable cultivation, various micronutrients including copper, manganese, iron, nickel and especially zinc have great impact on animal's wellbeing – for example cows. Those elements have positive effect on milk production, pregnancy and fertility. Unfortunately, the basic feed for animals such as grass is rarely analyzed on amount of nutrients therefore animals frequently end up being sick and unproductive. (MTT Agrifood Research Finland, Pesonen 2013.)

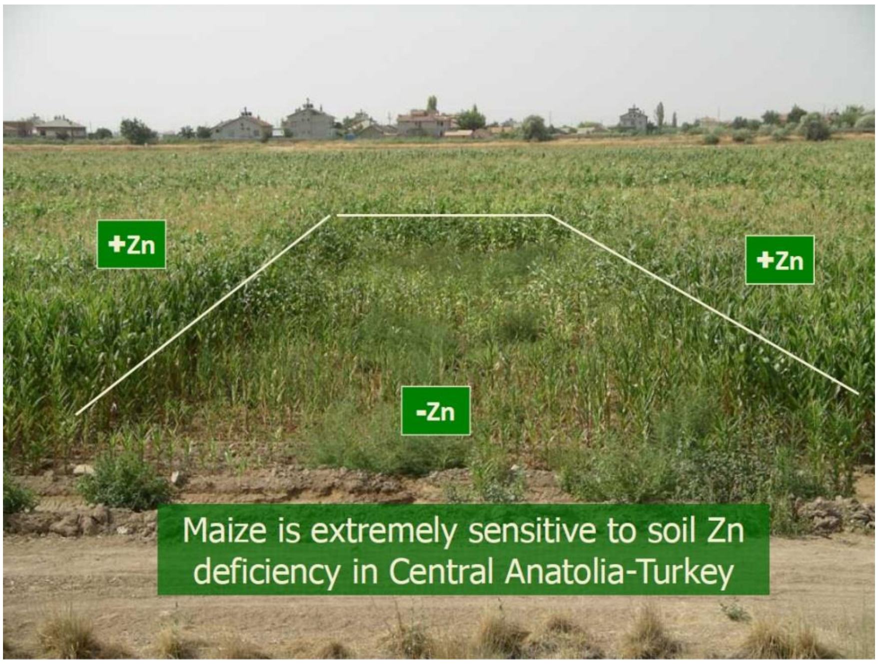
The map below represents the scale of Zinc deficiency problem. As you can see, enormous areas of fertile soils, specifically near the equator, are suffering from lack of Zinc, while vast areas of Africa, Europe and Eurasia are facing Zinc deficiency in humans as well. Black areas in Southern Africa and

South-East Asia are in most concerning situation as both population and soils suffer from serious deficiency.

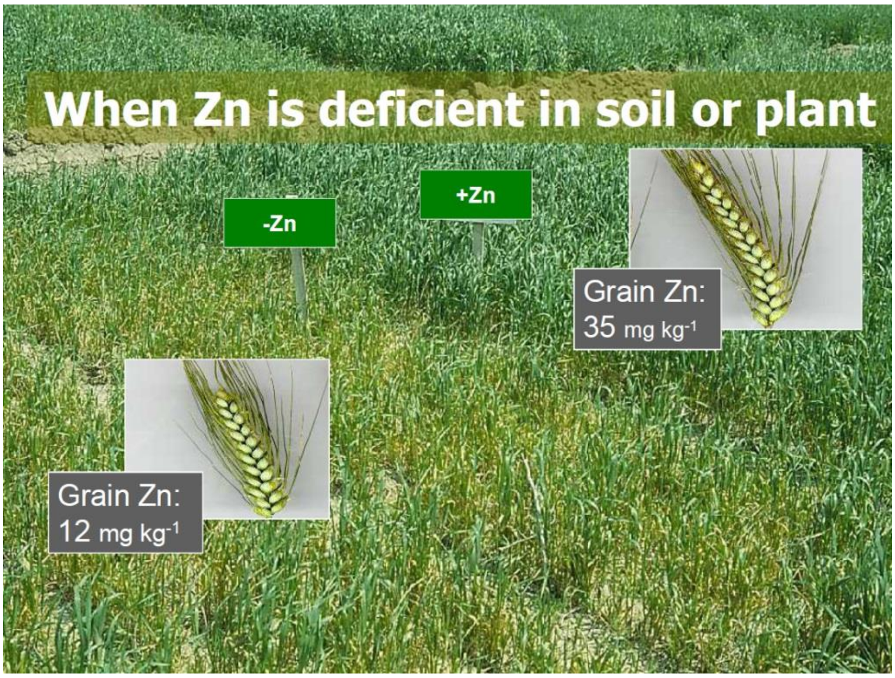


PICTURE 6. Map of Zinc Deficiency (Roots for Growth)

Pictures on the following page are showing what a huge visual difference exists between plants rich and poor with zinc.

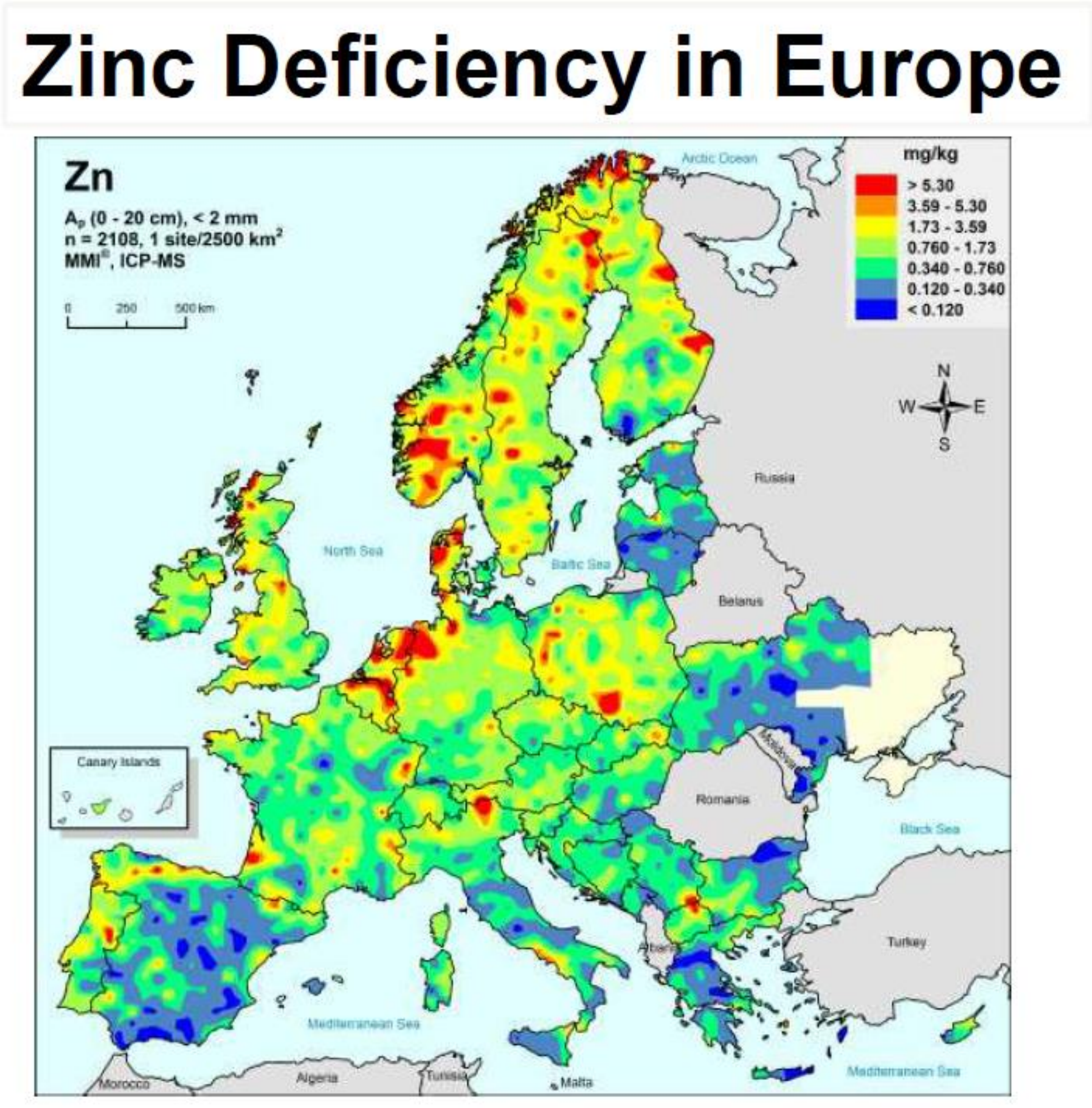


PCTURE 7. Zinc affecting maize plantations in Turkey (International Zinc Association, 2016)



PICTURE 8. Zinc amount difference in grains (International Zinc Association, 2016)

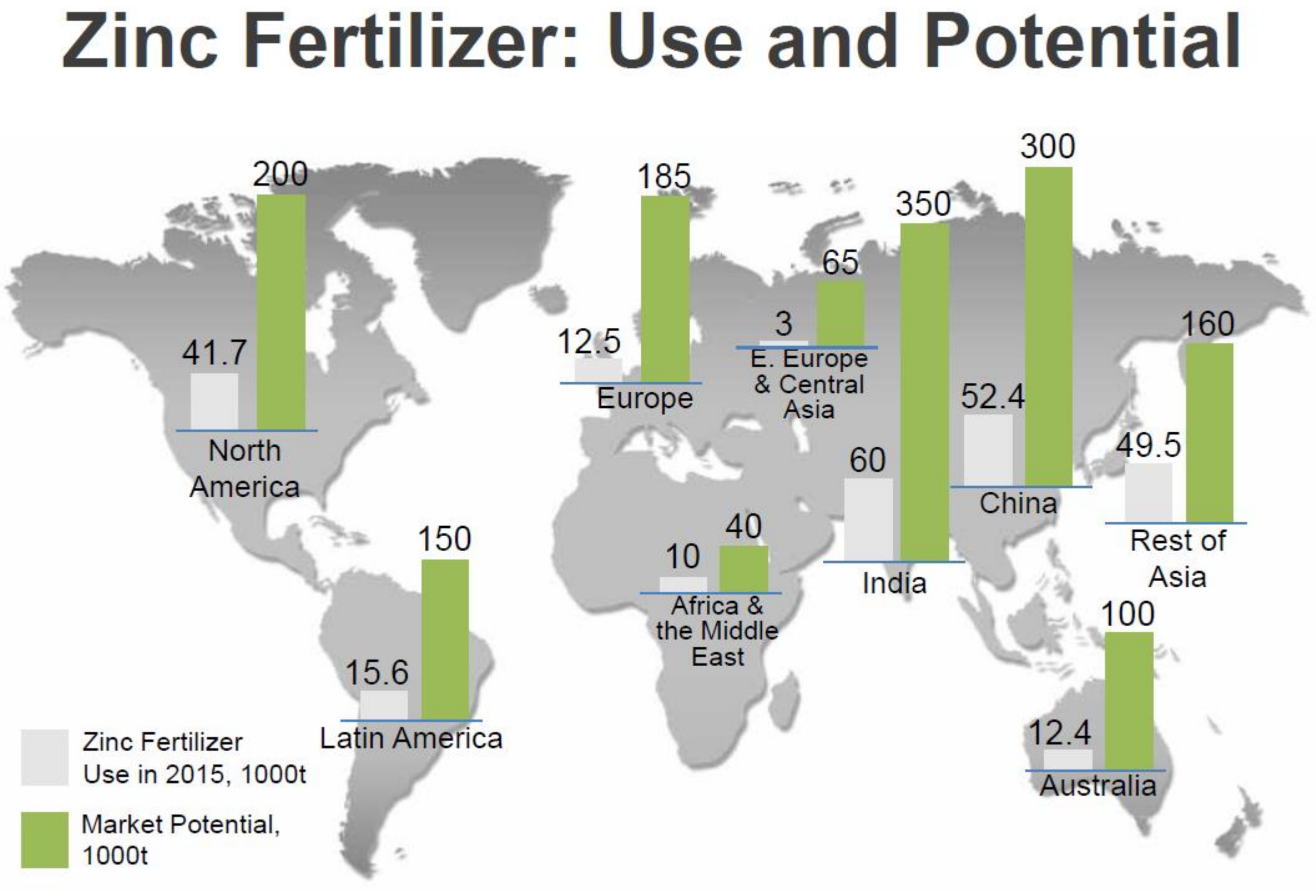
A recent research done in 2014 involving soil tests across Europe shows the amount of zinc in the soils. Graph range lies between 0.12 mg to 5.3 mg per kilogram of soil. Belarus, Romania, Eastern Ukraine and Russia were not observed, but judging by surrounding territories Zinc deficiency is a major problem throughout the region. Relatively high amounts were detected in the Netherlands, Belgium, Denmark and small areas in Scandinavia. The map pretty much sums up critical situation of Zinc necessity and potential markets in desperate need of efficient micronutrient fertilizers.



PICTURE 9. Zinc deficiency across Europe (Mann Et Al. 2014, Fig. 13.17, page 219)

Regarding soils in Russia I have found a rather controversial data. Some sources, especially agricultural books from Soviet Union, claim high amounts in various soils across former USSR territories. For example, “micronutrients and fertilizers” written by Katalymov M.V. in 1965 states that zinc content in the soils of CIS countries ranges from 25 to 100 mg / kg, and an average amount is 50 mg / kg. However, some sources containing articles dated at 2015 are showing zinc deficiency as a serious problem in agriculture. The content of mobile zinc compounds in soils is 0.2-2 mg / kg. Almost 60% of agricultural soils have low content of zinc- in average 0.2 mg / kg, and this is not sufficient for the formation of high yields of many crops. Important to remember, that before the application of any micronutrient fertilizer it is crucial to make soil tests and estimate if a certain field has significant zinc deficiency or if adding fertilizer will harm and poison the plants. (Agrocounsel, Zinc for plants.)

Last but not least, Picture 10 below illustrates what a great potential fertilizers containing zinc have on an international market. As we can see, demand for zinc fertilizer in every region of the world exceeds current numbers multiple times with highest potential in India and China.



PICTURE 10. Map of Zinc fertilizer usage and demand (International Zinc Association, 2016)

3.2.2.2 Manganese

In the previous chapter I have provided detailed data on the importance of zinc as a micronutrient in agriculture. Despite the fact of its obvious benefits to plants, zinc works much better in connection with Manganese, which is the second most used component, by quantity, in alkaline batteries. It is an essential nutrient for the functioning of the green fractions and it contributes to a better absorption of all other nutrients. For instance, manganese accelerates germination and maturity of growing crop by increasing the availability of phosphorus (P) and calcium (Ca). Manganese participates in the protein formation and helps to retain nitrogen in the plant. The apparent lack of manganese reduces the formation of lignin, the plant leaves begin to fade and root growth significantly slows down. Superoxide dismutase (SOD) is a manganese-containing ferment which plays an important role in plants and fights against oxygen free radicals. Free oxygen radicals destroy the cell walls and proteins. This is reflected in a defected color of leaves. Picture 11 below illustrates how severe manganese deficiency looks like on plant’s leaves.

PICTURE 11. Leave suffering from manganese deficiency (Manganese deficiency symptoms)

Manganese distribution in the thickness of the soil is uneven. It is concentrated not only in the form of concretions, but also in the form of various compounds enriched with other elements. Characteristically, the marked wide range of Manganese concentration does not depend on the type of soil. The highest content observed in soils developed on basic rocks, rich in iron and organic matter.

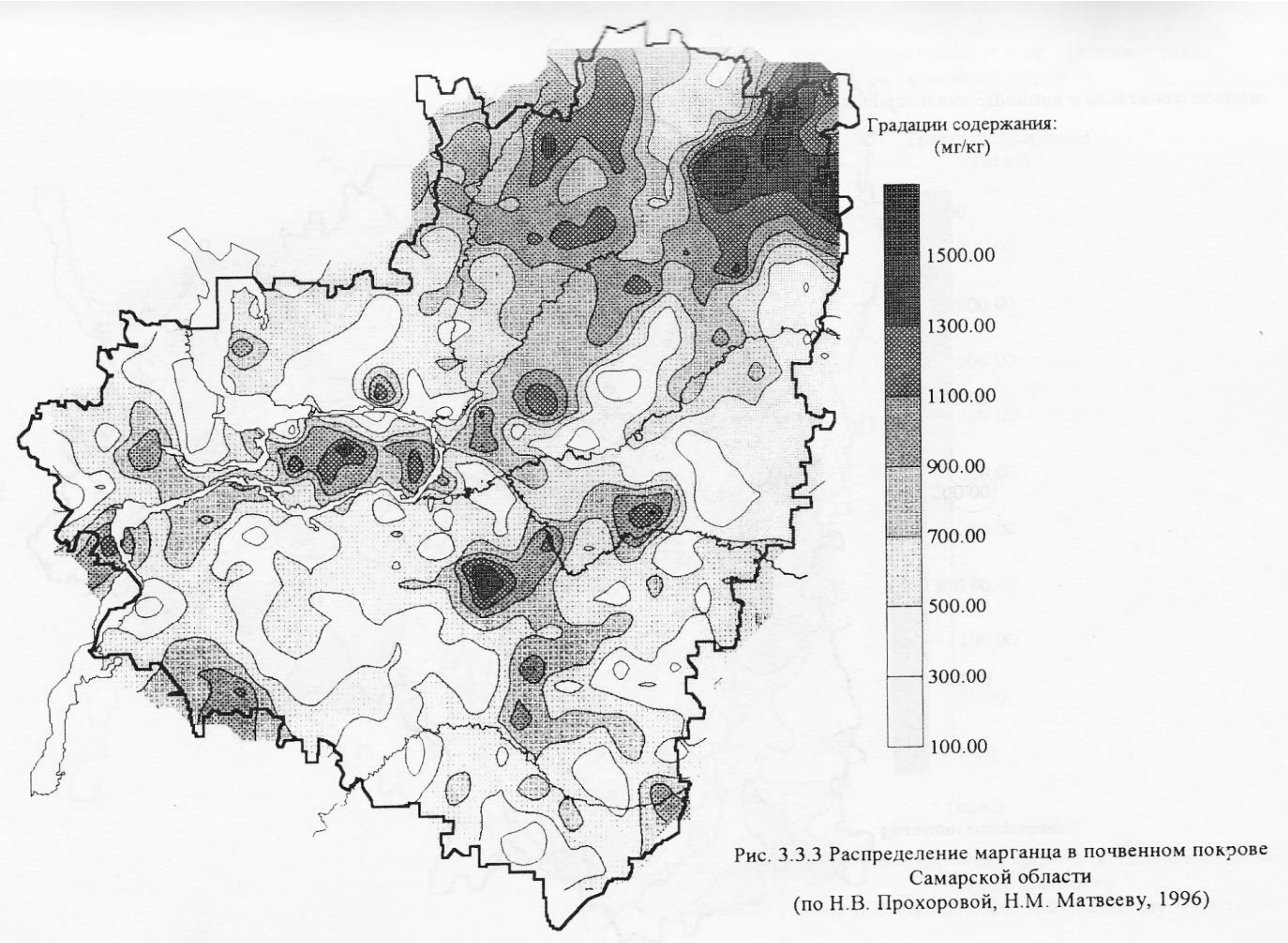
The soils contain manganese in form of salts, oxides, hydroxides and complex ions.
Orientation of redox reactions involving Manganese depends on the activity of microorganisms involved in the accumulation and oxidation of the element. Manganese forms compounds with humic substances of soils. Manganese compounds with fulvic acids have a high migratory ability and availability to plants. The main barriers to the movement of manganese in the soil are alkaline environment, carbonates, as well as increased content of humus.

The manganese content in the soils of the plains area of Russia and the CIS countries ranges from 0.1 to 4 g / kg of soil. On average, this parameter is about 1 g / kg. However, various types of soils vary considerably in the total content of manganese. Total manganese content may vary from 43 to 1800 mg / kg. In the CIS countries the limits of manganese content fluctuations are:

- Podzols and sandy soils in range of 135-310 mg / kg
- Clay and loam soils - 270-1300 mg / kg
- Chestnut and brown soils - 390-580 mg / kg
- Saline lands and salt marshes - 265-1100 mg / kg
- Chernozems - 340-1100 mg / kg
- Meadow soil - 690-1250 mg / kg
- Peat and other organic soils - 510-1465 mg / kg

Despite the considerable content of manganese in the soil, most of it is present in the form of poorly soluble compounds. The plants absorb from the soil only divalent manganese. Therefore, the degree of availability and the level of assimilation of manganese plants are closely related to the reaction of the soil solution. In neutral and mildly alkaline soils, manganese is in the three-and tetravalent compounds, which are inaccessible for plants. Symptoms of manganese deficiency in plants are observed primarily on calcareous, strongly limy, peat and other types of soils with acidity level higher than 6.5. This is explained by the fact that with an increase in the acidity of the soil by 1.0, manganese content of soluble compounds is reduced by 10 times. (Agrohimija, Manganese in soils.)

Unfortunately, it is rather challenging to find maps of Russia with manganese level illustrated in relation to agriculture, there are few regarding pollution from various heavy industries. Nevertheless, it is possible to assess the difference of manganese concentration on the example of Samara region in south Russia using Picture 12.



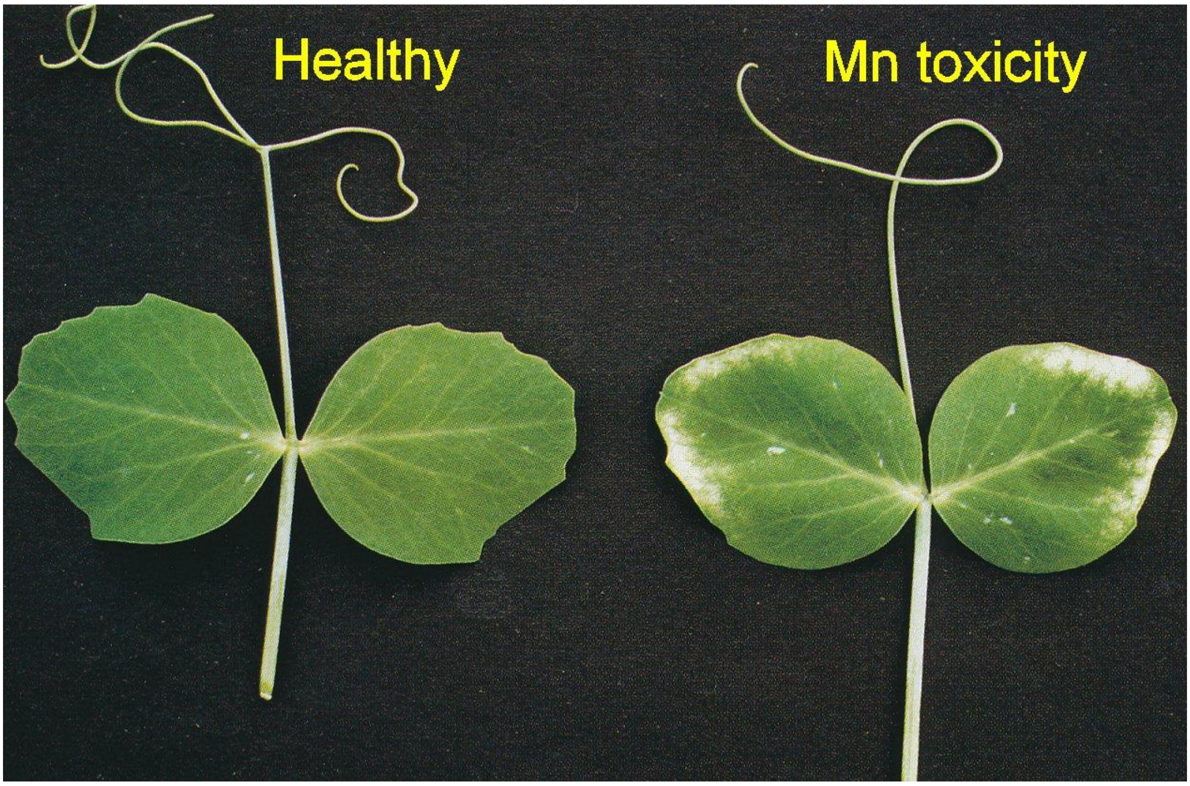
PICTURE 12. Range of manganese content in soils of Samara region (Prohorov, Matveev, 1996)

Manganese is absorbed by plants and is distributed in their systems as a result of metabolic processes. Manganese has a high degree of absorption and rapid transporting ability in plants. In the plant extracts and fluids the element is present in the form of free cationic forms and is transported in the form of Mn2 +. Manganese is transferred mainly in meristematic tissues, and can be usually found in significant concentrations within young plant organs. Manganese is necessary for all plants, without exceptions. One of the most important functions of this micronutrient is participation in redox reactions. Manganese is actively involved in the process of photosynthesis, specifically in its oxygen generating system, and plays a major role in the transportation of electrons. A form of manganese which is weakly bound in chloroplasts is directly involved in oxygen separation, while firmly bound form - in the transfer of electrons.

Manganese in plants primarily activates the action of different enzymes, which are of great importance in the redox processes, photosynthesis, respiration, etc. Along with calcium, it provides selective absorption of ions from the environment, reduces transpiration, increases ability of plant tissues to retain water, accelerates the overall development of the plant and has a positive effect on their fruiting. Under the influence of the manganese the synthesis of vitamin C, carotene, glutamine, increased sugar content in the roots of sugar beet and tomato, as well as the starch content in potatoes significantly enhances. Manganese is involved in the oxidation of ammonia, reduction of nitrates. Worthy to notice, that higher the level of nitrogen nutrition increases the importance of the role of manganese in plant development. (Agrocounsel, Manganese for plants.)

Various crops during the harvest period are losing from 100 g / ha (barley) to 600 g / ha (sugar beet) of manganese. Major quantity of element is localized in leaves, in particular in chloroplasts. In plants manganese, same as iron, is inactive, so the symptoms of its lack are most likely visible on young leaves – they tend to get covered with yellow-green spots and brown and white patches, their growth slows down. Gray-green or brown spots appear at the bottom of the leaves' edges, often followed by dark borders. Symptoms of lack of manganese are usually the same as of iron deficiency, only the green veins typically do not stand out as bright on the yellowing tissues. In addition, brown necrotic spots appear very quickly. The leaves die off faster than with the lack of iron. At the same time, plant tissue gets increased concentration of the basic elements which is breaking optimum ratio between them. Lack of manganese in the soil seriously affects some cereals, particularly oats and maize, beans, beets, potatoes, apples, cherries and raspberries. In fruit plants manganese deficiency leads to chlorotic leaf disease, weak foliage of trees, premature leaf fall and, in worst cases, drought and death of top branches. In addition, manganese deficiency intensifies by low temperature and high humidity, so the winter grain crops are more sensitive to its lack during early spring. (CropNutrition. Manganese. 2016.)

At the same time, the excessive nutrition of manganese results in young leaves turning to yellow-white color, old leaves get spotted and quickly die off. What is more, the root system of plants ends up being poorly developed due to the deceleration of cell growth. Picture 13 illustrates how overdose of manganese affects pea leaves. (Diagnosing manganese toxicity in field peas. 2015.)



PICTURE 13. Comparing healthy and manganese-toxic pea leaves (Department of agriculture and food, Western Australia, 2015)

Manganese fertilization has an overall positive effect on any plant's growth, but there are few differences:

- *Root crops of sugar beet* - under the influence of manganese fertilizer the yield and sugar content increase.

- *Alfalfa, clover and other grasses* - it enhances the growth and development, increases productivity.

- *Potatoes, cabbage, cucumbers, tomatoes, eggplants* - great surplus in yield.

- *Fruit and berry plants* - adding manganese has a positive impact on the condition and development. Increased yield and sugar content of berries, vitamin C content increases

- *Cereal crops, silage corn and cotton* - the use of manganese fertilizer improves crop yields. (Grigorovskaya, Manganese, 2013.)

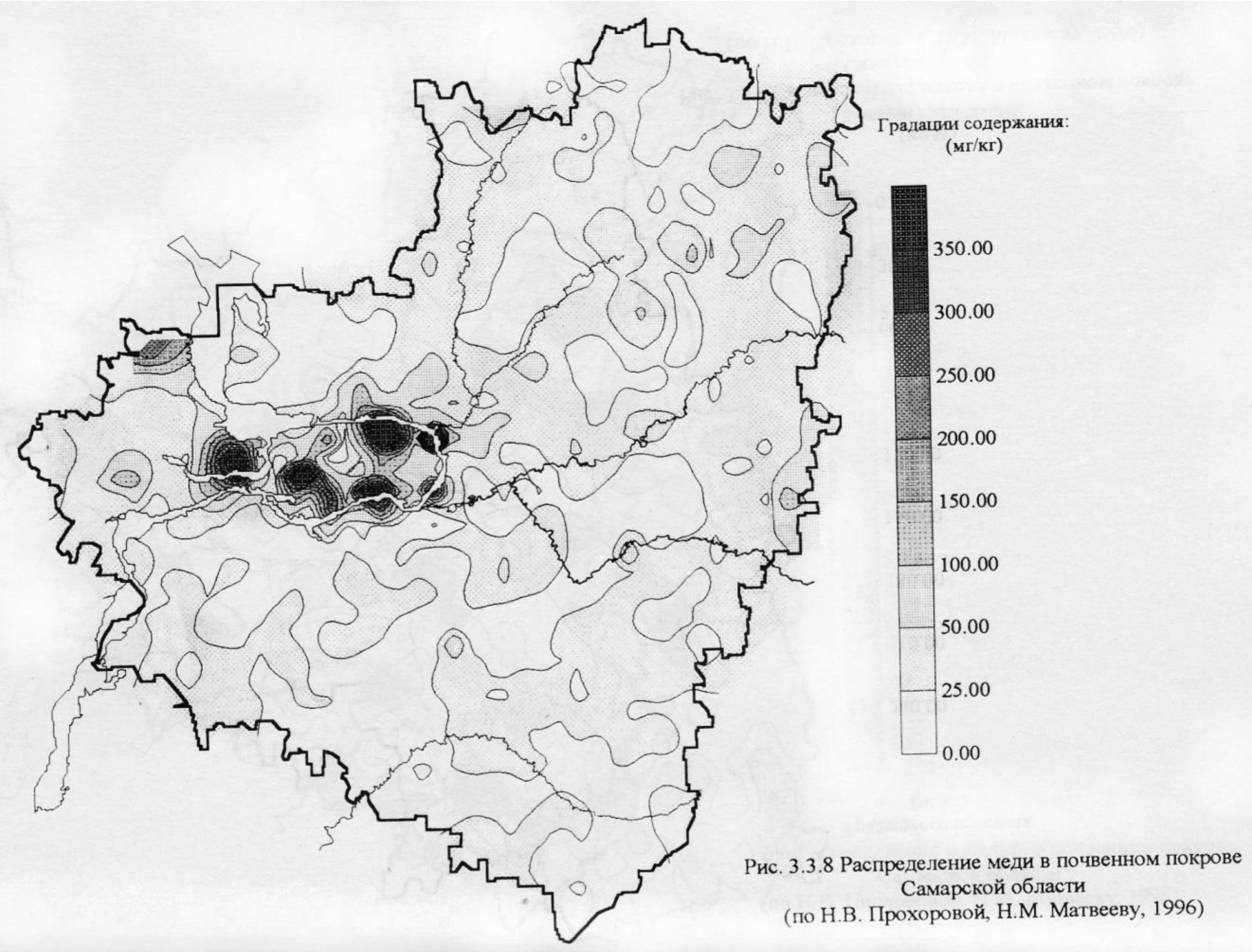
3.2.2.3 Copper

The Earth's crust contains only 0.01% copper. Distribution in nature is relatively low. Copper can be found in the free state in the form of nuggets, sometimes very considerable size. But ore of native copper is relatively rare - it does not exceed 5% of total extraction in the world.

The initial state of the distribution of copper in the soil is controlled by two factors: the processes of soil formation and the parent rock. A common feature of the distribution of copper in the soil profile is its accumulation in the upper layers. This reflects its bioaccumulation and the influence of anthropogenic factors.

In soil, copper is separated into the following forms: exchangeable (absorbed organic and mineral colloids), water-soluble, sparingly soluble copper salts, copper-containing minerals and complex organic compounds. Solubility of cationic and anionic forms of copper is reduced when pH acidity level reaches 7-8 points. The key reaction of the copper contained in the soil is complex formation with organic compounds. Humic substances together with copper form soluble and insoluble compounds. The most available forms of copper for the plants are water-soluble copper compounds.

Content of copper in Russia varies quite much, from 1 to 100 mg / kg. Very high copper amount is usually traced in soils formed on the copper-rich rocks and areas of concentration of copper deposits. Significant enrichment of soils with copper can be detected in case of frequent plant protection agent fertilization of fields which contain copper. Picture 14 below shows how low is the amount of copper across the Samara region with exception of the central area due to contamination appearing from metal industry.



PICTURE 14. Range of copper content in soils of Samara region (Prohorov, Matveev, 1996)

Another map is related to Moscow and its surroundings, where copper was measured as a part of environmental pollution. Light beige colored regions represent very low amount (less than 5 mg / kg), beige areas show low concentration in range of 5-15 mg / kg, purple area on the east from Moscow points at medium content and few areas painted in blue were not tested due to unknown reasons.

PICTURE 15. Map of Moscow region, copper concentration in soils (Soyuz-T, 2009)

Locations and principles of behavior of copper within plants are divided into six groups:

- Copper is present in compounds with proteins and low molecular organic compounds.

- Copper is found in some of the enzymes - substances essential for plant but with yet unexplored functions.

- Copper plays an important role in the processes of respiration, photosynthesis, redistribution of carbohydrates, nitrogen fixation and recovery, creation of cell walls and proteins.

- Copper influences the water access to xylem vessels and water balance control.

- Copper controls the formation of DNA and RNA.

- Copper has a significant impact on the mechanisms of plant resistance to various diseases. However, in case of an excess or high copper content in plants, they become less resistant to certain diseases.

Biochemical properties and functions of copper are similar to those of iron and both elements are capable of forming stable complexes and change divalent valence to monovalent. Monovalent copper is very unstable, unlike divalent. The question of the form in which copper is absorbed by plants, currently remains without certain answer. Up to 99% of the copper is present in plants in the form of complex shapes and quantity of free mono- and divalent ions is extremely low. Also copper is characterized by greater similarity to amino acids rather than to organic acids. (Grigorovskaya P. 2013. Copper)

The disease caused by lack of copper is called the white plague or disease of treatment. Copper deficiency causes stunted growth, chlorosis, turgor loss and, as a consequence, faded leaves, delay of blooming and death of harvest. In cereal crops significant shortage of copper can be seen in whitening of the tips of the leaves and undeveloped ear of wheat. Fruits suffer from dry tops leading to tree's death. Copper deficiency usually occurs in plants in sandy acidic and peat soils. The critical level of copper shortage is observed when the copper content in the vegetative parts of plants is less than 5 mg / kg of dry mass. Typical anatomical abnormalities arising from copper deficiency are directly related to the violation of lignification of the cell walls. To the greatest extent this is reflected in dying tissues of stem cells. This phenomenon can be observed even with a slight decrease in the level of copper and can be used for diagnostic purposes. Decrease in the activity of copper-containing enzymes involved in respiration and photosynthesis processes is significant if plant suffers from a lack of copper. As a consequence, the number of soluble hydrocarbons in plants is being reduced. In case of low copper content pollen formation is disturbed, what leads to overall reduced fertility and suppressed nitrogen fixation in beans. Copper deficiency has greater effect on seed and grain development, rather than on the vegetative growth of weight. Therefore, plants require more copper for the normal formation and function of the generative organs rather than for the vegetative parts themselves. Violation of photosynthesis and respiration caused by lack of copper negatively affects the energy exchange inside the plant, what triggers a chain reaction of secondary physiological effects. What do plants miss? (World of plants and trees Journal. 2015)

If copper content in the soils is less than 1.5-2.0 mg / kg, soils are considered poor with this micronutrient and plants are suffering from major copper deficiency. Picture 16 below clarifies how significant lack of copper is displayed on leaves of cucumber, tomato, clover and potato.

PICTURE 16. Copper deficiency on various plants (World of plants and trees N.3 (84), 2015)

CLASSIFIED Here are actual effects of fertilizers containing copper on different plants and on various soils:

corn, flax, forage crops on drained swamps and other soils. Copper fertilizers are highly effective, enhancing productivity and improving product quality. An experiment documented in an agrochemistry school book written by V.G. Mineev back in 2004 found out that the injection of copper fertilizers increases the yield of wheat by 200-500 kg / ha, barley by 200-300 kg / ha, oat - by 400-600 kg / ha, enhances green mass of maize by 21%, and its ears by 9-13%.

Root crops of sugar beet in the sod-podzolic soil. Adding copper fertilizer increased the yield by 43-45%. What is surprising, the same culture treated with copper in rendzina (lime-rich with dark humus layer) soils which have sufficient natural copper amount did not bring any difference in yield.

Perennial herbs. After applying copper fertilizer, the yield of green mass increased, plus forage quality grass improved.

Potatoes in sod-podzolic soils. Addition of copper under certain conditions contributes not only to increase in productivity and improvement in quality of root crops, but also increases the plant's resistance against the late blight and blackleg disease.

Tomatoes. The copper-containing fertilizers help to increase yield and vitamin C content in vegetables.

Carrot. Application leads to increased productivity, carotene content, sugars, nitrogen.

(Micronutrients: directory, Anspok, 1990.)

3.2.2.4 Iron

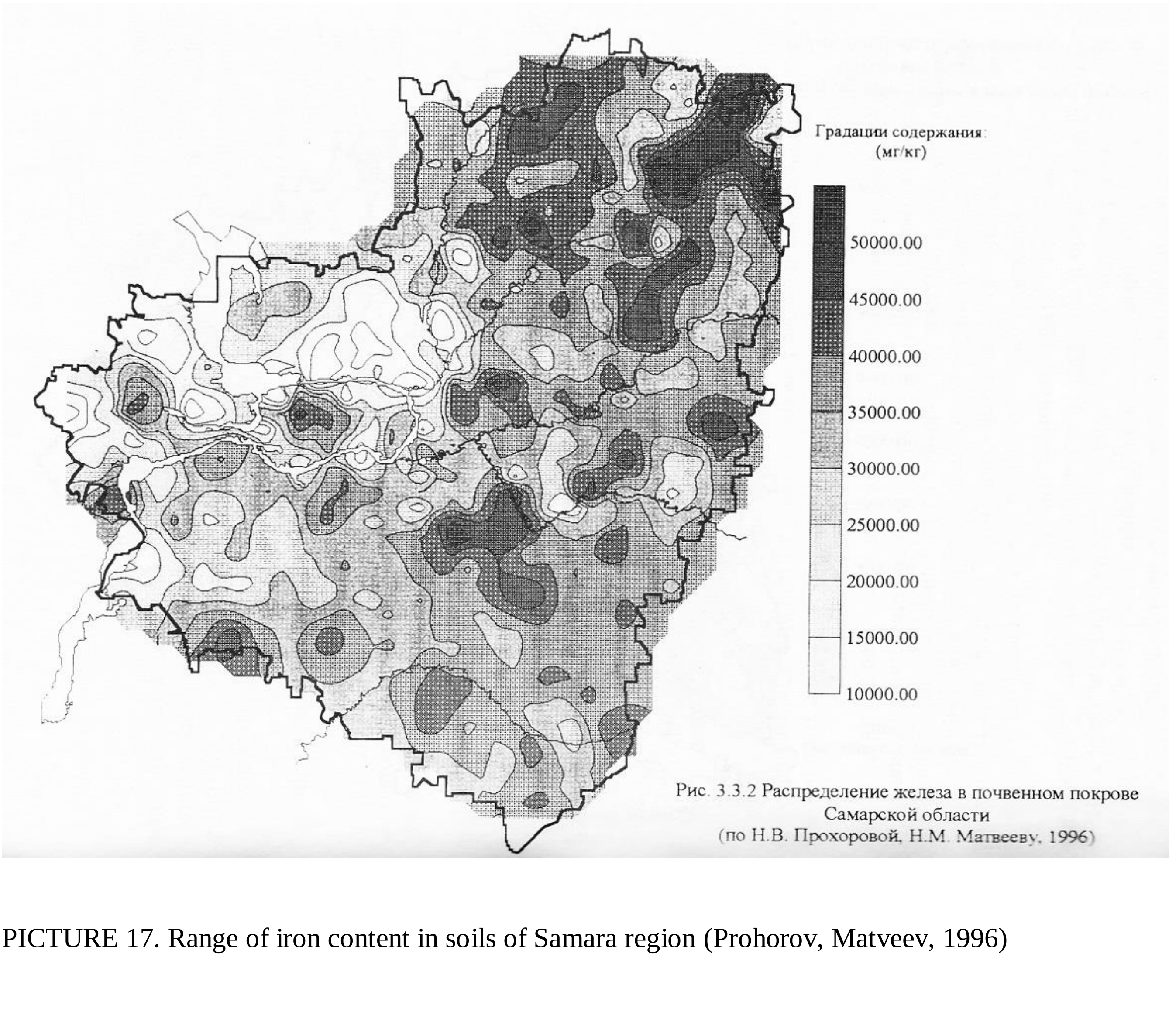
Iron is the most common metal in the world after aluminum. Its weight is 4% of the weight of the earth's crust. In nature, it occurs in a wide variety of compounds: sulfides, oxides, silicates. In the pure condition, iron can be found only in meteorites.

Geochemistry of iron compounds in the environment is very complex, it is determined by the element’s ability to easily change the valence depending on the physico-chemical conditions of the environment and is closely related to the cycles of carbon, oxygen and sulfur. Typically, the oxidizing and alkaline environmental conditions help iron precipitation, while recovery and acidic conditions are dissolving iron compounds.

In soils iron is present mainly in the form of oxides and hydroxides and is either spread in the form of small particles or associated with the surface of minerals. The organic-rich layers contain iron in the form of chelates.

Minerals and organic compounds of iron are easily transformed in the soils. What is more, organic material has a great influence on the formation of iron oxides. Compounds of iron and soil organic matter are important reserves of metal compounds available for plants. Also, the conversion of iron can be carried out with microorganisms. Some types of bacterias are involved in the natural cycle of the micronutrient and are able to accumulate iron on the surface of living cells. (Bibleotekar. Iron)

The content of iron in the Russian soils is about 3.11%, depending on the type of parent rock. It was found that variations of the iron content in the arable areas of different soils are significant. However, only a small part of the iron in the soil is available for plants' nutrition. Evidences of iron deficiency in crop plants occur much more frequently than it could have been expected taking in account such a high concentration of iron in the soil. As an example of iron concentration in soils, map of Samara region in Picture 17 below illustrates that there is no deficiency in soils, however the widespread iron compounds cannot be consumed by plants.



PICTURE 17. Range of iron content in soils of Samara region (Prohorov, Matveev, 1996)

Iron mobility decreases sharply in neutral and low level alkaline soils, what leads to some plants, particularly fruits, berries and vegetables, suffering from lack of this element. Adding dissolved iron salts to the soil is useless because they turn quickly and completely into compounds, inaccessible for plants. Spraying fertilizer containing iron is more efficient, but it is required to carry out two or three times during the season to gain any improvement in the quality of harvest. **CLASSIFIED**

Iron plays an active role in the redox reactions of chloroplasts and performs many other functions in plants. Iron's participation in the redox reactions is determined by the light change of valence and a high ability to form complex compounds.

Important role of iron in plant biochemistry is confirmed by the following factors:

- Iron is found in heme and non-heme proteins and concentrated in chloroplasts.
- Organic iron compounds are involved in electron transfer during photosynthesis.
- Non-heme iron-containing proteins participate in the restoration of nitrites and sulfates.
- The formation of chlorophyll is implemented with the participation of iron.
- Iron is involved in metabolism of nucleic acid.
- Catalytic and structural role of divalent and trivalent iron is a common knowledge

In order to ensure normal development and in particular the synthesis of chlorophyll the plant must absorb the iron. The soil is usually well supplied with iron, but the amount absorbed by the plants is small. Iron chlorosis, which can be noticed in yellowing of green parts (the disappearance of chlorophyll), is not always connected to iron deficiency. More often the reason is that iron's consumption is slowed down by the absorption of excess calcium, which connects iron in the soil.

Chlorosis (bleaching) of plants develops along with a deficiency of iron in the soil, excessive moisture or low temperatures of soil and air. Adding iron to the soil, foliar feeding of plants with iron salts, the removal of unnecessary soil moisture and acidification of carbonate soils prevent the development of chlorosis.

With a lack of certain nutrients some plants tend to get sick. Lack of iron in the soil causes chlorosis, what is often occurring in the vineyards, berry bushes and fruit crops. If there is not enough moisture the plants are going to dry up and an excess of water leads to plants getting rotten.

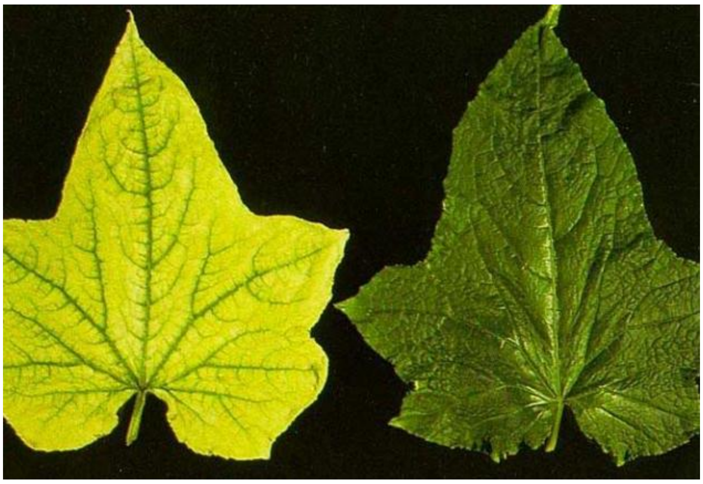
Iron deficiency is also seen in cases of high content of manganese, zinc and copper in the soil. Lack of iron affects the growth of leaves to a much lesser extent, while cell division and slower growth only occur in serious iron deficiency. The most significant changes appear in the plastid apparatus of leaves. Plastids decrease in size, thylakoid system becomes reduced. Protein synthesis in the cytoplasm and especially in chloroplasts starts to be suppressed.

To sum up, iron deficiency affects the decrease in chlorophyll content of leaves and suppressing the activity of photosystems. The changes affect the photosynthesis carbohydrate metabolism of plants, in particular, a decrease in the content of sugar and starch in leaves. (Grigorovskaya, Iron, 2013.)

Visually, iron deficiency symptoms are as follows:

- Whitish, pale green or yellowish color of the leaf tissue between the veins becomes noticeable.
- With stronger iron deficiency leaf veins get pale and tissue dies off.
- Due to low iron reutilization old leaves remain green longer, therefore the first symptoms appear on young leaves.
- The top young leaves of grass turn yellow, forming small, weak buds. Fruit trees are suffering from shrinkage of the tips of branches and shoots.

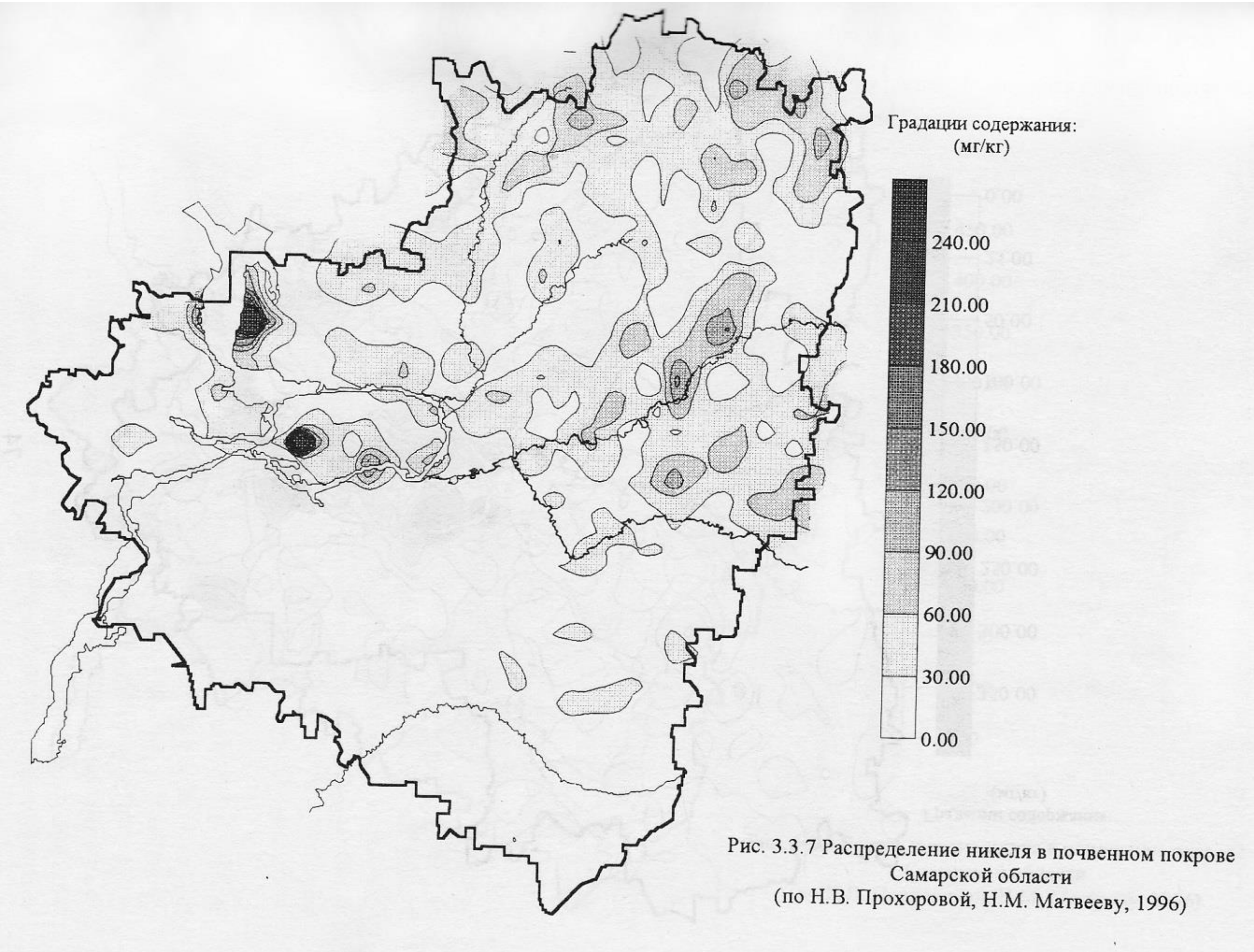
(Hydroponics. Iron deficiency in plants, 2015.)
The symptoms of iron deficiency can be clearly seen on Picture 18 in comparison with healthy leaf.



PICTURE 18. Leave suffering from lack of iron and healthy leaf (Hydroponic plants, 2015)

3.2.2.5 Nickel

Nickel is quite common in nature - its content in the earth crust is approximately 0.01%. Inside the earth's crust nickel is found only bounded in compounds, however, iron meteorites contain pure native nickel (from 5 to 25%). Nickel isomorphically replaces iron and magnesium. Small amount of the nickel is present in form of sulphides. Nickel shows siderophile and chalcophilic properties. In case of higher sulphur content in magma nickel appears as a sulphide with copper, cobalt, iron or platinum. A map of Samara region on Picture 19 below shows how rare is nickel in soils.



PICTURE 19. Range of nickel content in soils of Samara region (Prohorov, Matveev, 1996)

Nickel - a necessary micronutrient for plants. In complex plants nickel is a part of the urease enzyme which is responsible for the decomposition reaction of urea into ammonia and carbon dioxide. It has been proven that in plants with sufficient nickel amount urease activity is higher, therefore such plants have lower urea content compared to unsecured plants. Nickel activates several enzymes, including - nitrate reductase, hydrogenase, and others. Nickel has a stabilizing effect on the structure of ribosomes, also it is involved in the transportation and provision of nitrogen for the plant tissues. (Wikipedia, Nickel: being in nature.)

A series of experiments have found out the positive effect on crop yield because of the application of nickel in soil, what is probably due to the stimulation of microbial processes of nitrification and mineralization of nitrogen compounds in the soil. Nickel comes to plants in the form of ion Ni2 +, but may be in the form of Ni + and Ni3 +. Some experiments have found out the relationship between nickel amount and plant’s ability to fight diseases, but it is not yet clear what exactly generates such results.

Typically, the nickel content in plants does not exceed 0,005 mg % (by weight), but some plants like tea, cocoa, buckwheat, carrot or lettuce contain a lot of this element. Some microorganisms play a role of nickel concentrators, they may contain thousands, even hundreds of thousands of times more nickel than the surrounding environment. **CLASSIFIED** (Pharmacognosy. Nickel for plant: Access of Nitrogen..)

Nickel deficiency in general leads to a reduced rate of plant growth and decreased biomass accumulation. Visual symptoms can be seen only in cases of severe deficiency and old leaves get affected in the first place. Leaf tips tend to die due to toxic levels of urea and whole leaves are losing their color as chlorosis gains power. Nickel deficiency may be noticed in spring on early growth stages of trees as the distance between internodes decreases, terminal buds die and eventually branches cease to exist. Other possible symptoms are slower growth of leaf blades, death of leaf tips and mouse-ear – short and rounded form of leaf. Picture 20 is showing necrosis of leaf top in case of nickel deficiency, while Picture 21 illustrates difference between surplus and lack of nickel within branches of pecan plant. (Buechel. T. Role of Nickel in plant culture, 2016; Holimoli. Nickel, 2015.)

PICTURE 20. Nickel deficiency leads to necrosis of leaf top (Brown, University of California, Davis)

PICTURE 21. Nickel sufficient and deficient levels (Bruce Wood, USDA-ARS, Byron, GA)

Nickel as majority of micronutrients tends to be absorbed better if the acidity level of soil is lower. High levels of other micronutrients may lead to nickel deficiency, which is why TraceMix has balanced amount of ingredients. As stated before, it is important to keep the balance of plant's nutrition. Nickel toxicity shows itself in the oppression of the processes of photosynthesis and transpiration, eventually leads to leaf chlorosis.

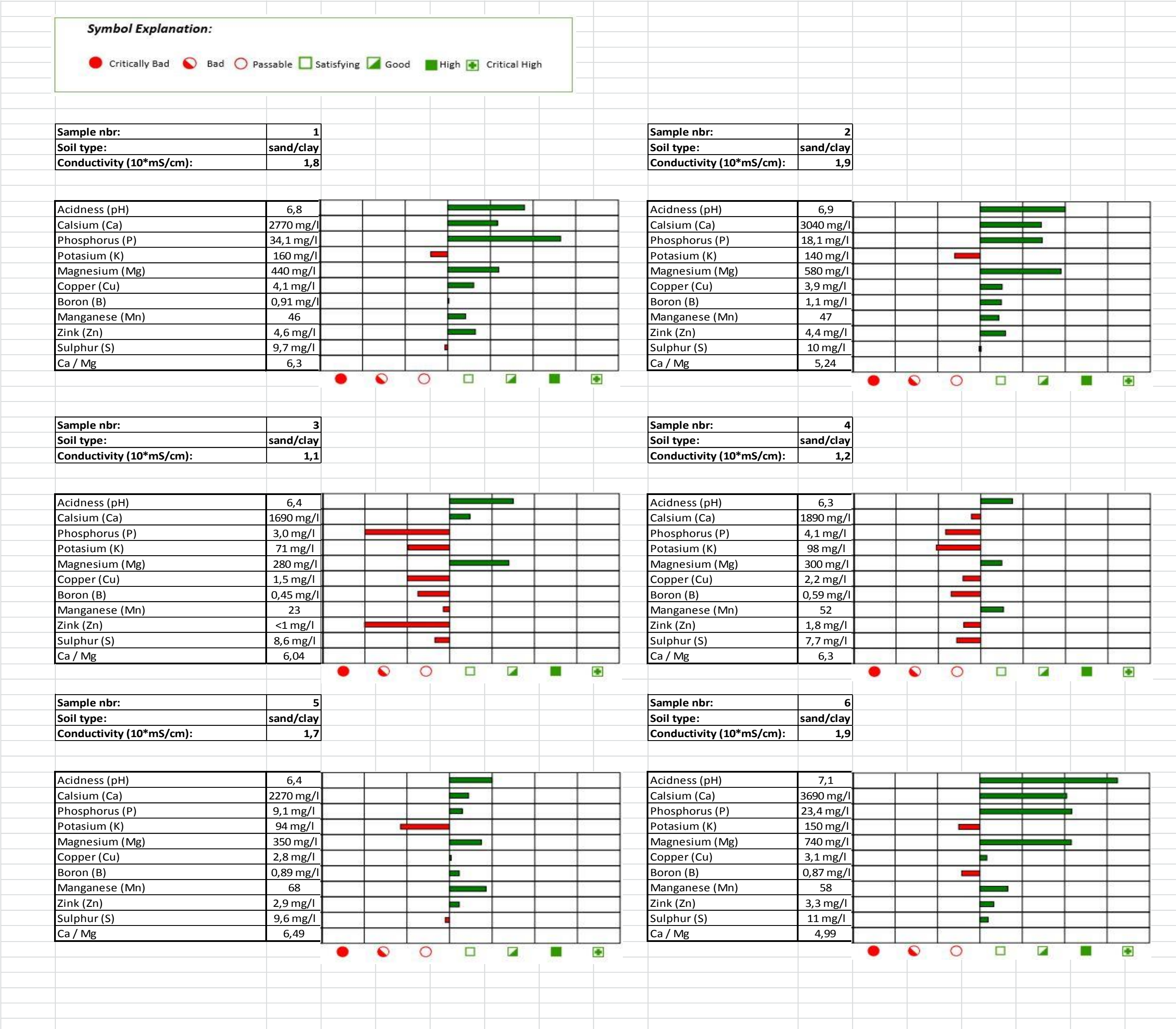
3.3 Importance of soil analysis

It is helpful to analyze each and every element of TraceMix because apart from undeniable positive influence on plant's growth, there might be also negative consequences if spraying was not done properly or overdose of elements occurred. Foliar fertilization is the most efficient way to apply micronutrients. While leaves of plants do not tend to absorb NPK elements, they can be more useful if applied directly into soil. Deficiency of Zinc and Manganese can be restored by foliar fertilizers in many cases, for example in vegetable cultivation in early spring when soil is cold and roots cannot produce adequate amount of natural micronutrients or in areas where soil has high pH (acidity level) which blocks micro-nutrient availability for roots. (Liquid vs dry foliar fertilization, 7.)

A micronutrient shall be applied to the plants only in case there was proper soil analysis done which has proven specific micronutrient deficiency. There is a thin line between helpful and toxic effect of mineral elements, therefore inadequate fertilization may result in loss of harvest and damage to the soil once its amount has exceeded the norm.

During my practical work for Rec Alkaline which will be described in the latter part of the thesis, I had to get soil samples for such analysis from a field assigned for TraceMix experiment.

TABLE 8. Soil analysis (own source, 2016)



Sample nbr:	1	2	3	4	5	6
Soil type:	sand/clay	sand/clay	sand/clay	sand/clay	sand/clay	sand/clay
Conductivity (10*mS/cm):	1,8	1,9	1,1	1,2	1,7	1,9
Acidness (pH)	6,8	6,9	6,4	6,3	6,4	7,1
Calsium (Ca)	2770 mg/l	3040 mg/l	1690 mg/l	1890 mg/l	2270 mg/l	3690 mg/l
Phosphorus (P)	34,1 mg/l	18,1 mg/l	3,0 mg/l	4,1 mg/l	9,1 mg/l	23,4 mg/l
Potasium (K)	160 mg/l	140 mg/l	71 mg/l	98 mg/l	94 mg/l	150 mg/l
Magnesium (Mg)	440 mg/l	580 mg/l	280 mg/l	300 mg/l	350 mg/l	740 mg/l
Copper (Cu)	4,1 mg/l	3,9 mg/l	1,5 mg/l	2,2 mg/l	2,8 mg/l	3,1 mg/l
Boron (B)	0,91 mg/l	1,1 mg/l	0,45 mg/l	0,59 mg/l	0,89 mg/l	0,87 mg/l
Manganese (Mn)	46	47	23	52	68	58
Zink (Zn)	4,6 mg/l	4,4 mg/l	<1 mg/l	1,8 mg/l	2,9 mg/l	3,3 mg/l
Sulphur (S)	9,7 mg/l	10 mg/l	8,6 mg/l	7,7 mg/l	9,6 mg/l	11 mg/l
Ca / Mg	6,3	5,24	6,04	6,3	6,49	4,99

On the Table 8 above you can see 6 different portions of soil collected from 1 hectare in Russia nearby Saint-Petersburg, 100 gram each. They show amounts of micronutrients in soil on specific parts of land. From these tables it is obvious how big the difference in soil is even if it is located several meters apart from each other. On the other hand, it is clear that soil has crucial deficiency of Zinc, Manganese, Potassium and Sulphur throughout all 6 samples. In order to gain maximum yield and have healthy plants the lines should be within “high” and “critical high” zones.

4 MARKET RESEARCH

The market research is based on several parameters including total area of arable lands, number of farms involved in local agriculture, list of potential customers regarding usage of fertilizers, amount and types of fertilizers sold and distributed across the region, potential competitors and their prices. Worthy to notice, research is restricted to area of Saint Petersburg and surrounding Leningrad region as the nearest region to Finnish border with high population and developed industrial sector including farming and production of fertilizers. These two areas are separated in all official statistics and documents because Saint Petersburg is a city of federal importance along with Moscow and Sevastopol.

4.1 General information

The region is one of the most populated in Russia due to developed infrastructure, job availability, cultural and geographical positions. The trend of migration to Saint Petersburg gets only stronger and in 2016 62% of population increase was due to migrants arriving mainly from other Russian regions and CIS countries. The unemployment rate is just 1,7% of economically active habitants. Population of the city grew from 5 131 900 in 2014 to 5 225 700 in 2016. Similar positive trend can be seen in the Leningrad region where population increased by 15 000 citizens in the past two years.

The ecological situation has been raising concerns of the public for a rather long time and the situation does not get better. Industries affect the environment by dumping dirty water and polluting the air. The first parameter dropped from 273 mln. In 2013 to 252 mln. M^3 in 2015, but the amount of unfiltered water went up by 7 million cubic meters. Pollution of air with contaminants is fluctuating around 247 000 tons during the latest years. In the Leningrad region, the situation with stock waters gets better and the number of cubic meters dropped from 1157 mln. to 1022 mln. during 2 years. The area of parks, gardens and lawns along highways in Saint Petersburg has increased by 360 hectares from 2013 to 2015 due to governmental program aimed at maintaining air purity and green landscaping.

According to statistics conducted in the end of 2015, turnover in agriculture, hunting and forest industry was 5.4 billion rubles and 69.4 billion in Saint Petersburg and Leningrad region respectively. Those numbers combined equal 1.1 billion euro approximately. The number of organizations working in agriculture, hunting and forestry, according to governmental statistical register is 1412 units in Saint Petersburg and 4740 units in the Leningrad region.

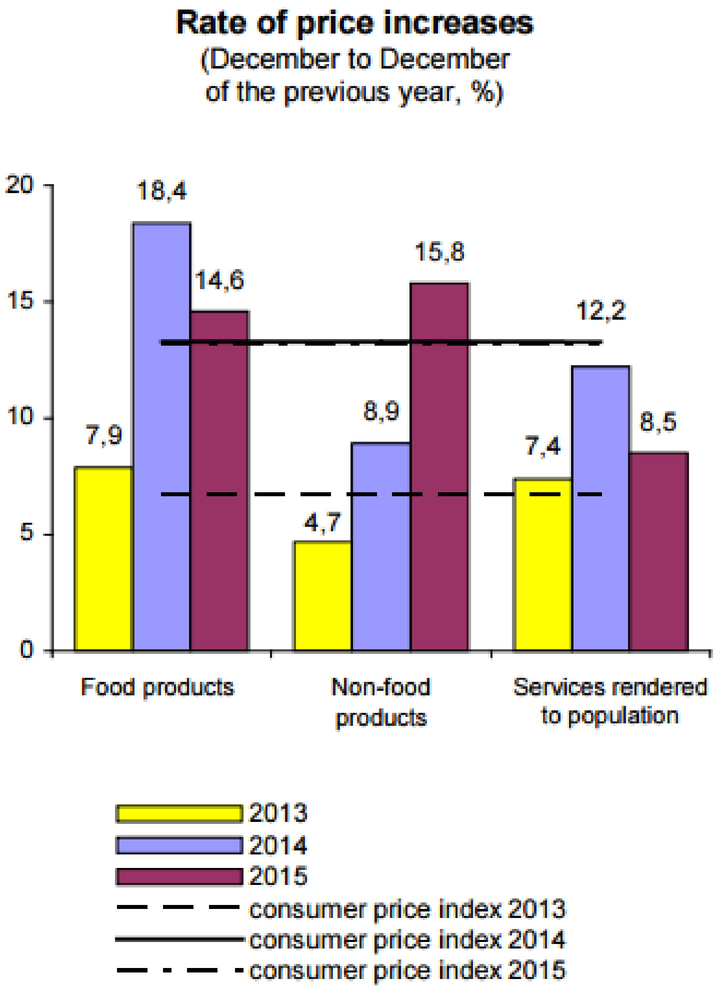
There are 14 organizations involved in agriculture within the borders of Saint Petersburg and its data is included in the Leningrad region. It was estimated that average yield from 1 hectare is:

- 2.34 tons of corn per hectare
- 19.66 tons of potatoes per hectare
- 40.71 tons of vegetables per hectare

What is more, these organizations sold 4.3 thousand tons of potato and 12 thousand tons of vegetables from January to October 2016.

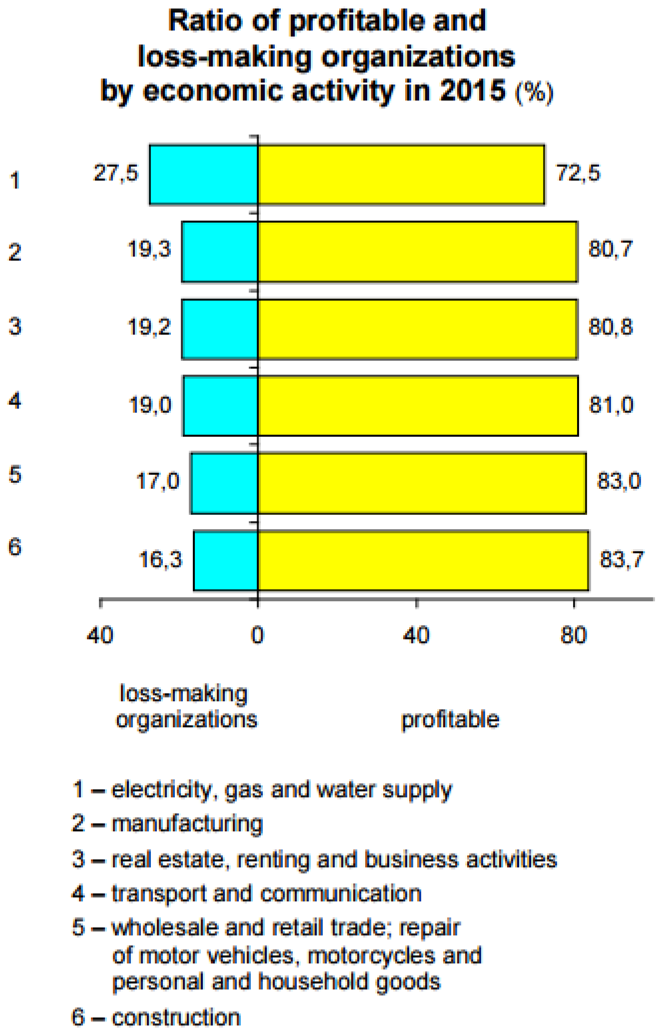
The volume of agricultural products in Leningrad region appeared to be 75.1 billion rubles from January to October 2016, what is 6.7% lower than in the previous year. Statistics regarding harvest collection claim that 41.2 thousand hectares of crops, 13.9 thousand hectares of potato fields and 5.8 thousand hectares of vegetables were harvested and 1221 thousand tons of crops, 2171 thousand tons of potatoes and 159.2 thousand tons of vegetables were collected. Ratio of harvest to seeds planted became lower than in 2015, for example crop yield this year has 87.7% of harvesting efficiency, while last year it was 96.4. Similar situation occurs regarding potatoes and vegetables. In 2016 harvest of crops from each hectare decreased by 23.2% comparing to previous year and stands at 2.97 tons. When it comes to volumes of sales in the Leningrad region, dairy products, meat and potatoes increased volumes, while sales of vegetables constitute only 65% of the amount sold in 2015. (Lenoblinform. General information on agriculture in the Leningrad region, 2016.)

In general, the economic situation of the region is challenging due to financial crisis nation-wide. There are key numbers below illustrating how the economy behaved during 2013, 2014 and 2015.



GRAPH 1. Rate of average prices (Petrostat, 2016)

The Graph 1 is showing a dramatic increase in price for majority of products and services, reaching double growth in 2014 while slowly stabilizing in 2015. Prices on non-food products continue to go up as Russian manufacturers are not able to satisfy all of the demand and items still have to be imported from European Union, what became more expensive due to the devaluation of the national currency - the ruble.



GRAPH 2. Ratio of profitable and loss-making organizations in 2015 (Petrostat, 2016)

Graph 2 shows an increase in number of loss-making organizations in Saint Petersburg. Especially commodities services are in a problematic situation as government controls moderate prices on gas, water and electricity to help citizens manage their spendings. Agriculture is not shown on this graph because this statistical data is included in Leningrad region.

Figures below are related to Leningrad region and describe various aspects of total economic conditions and concentrate on situation in agricultural sector.

TABLE 9. Part of labour market data (Petrostat, 2016)

Labour market

Average number of employees in organizations
(thousand persons)

	2013	2014	2015[1]
Total	518,4	516,6	514,1
including by economic activity:			
agriculture, hunting and forestry	38,0	36,1	33,8

The labour market in Leningrad region shrinks during difficult economic situation. Some industries managed to hire more workers but agriculture, hunting and forestry sector had to decrease the total number of employees.

TABLE 10. Part of information regarding salary level (Petrostat, 2016)

Accrued average monthly wages of employees in 2015[1]

	Nominal, rubles	Real, % of 2014
Total	33796	91,6
by economic activity:		
agriculture, hunting and forestry	28940	92,9

The salary level across the region has stayed at the same level and exceeds 500 euro per month in average. However, the rise in prices of main goods and services of daily life results in approximately 8% decrease of the real level of salary as people have to reduce their living costs.

TABLE 11. Part of information on turnover by industry in 2015 (Petrostat, 2016)

Turnover of organizations

Turnover of organizations by economic activity in 2015

	Billion rubles	% of the	
		2014[1]	total
Total	1846,1	113,0	100
including by economic activity:			
agriculture, hunting and forestry	69,4	111,1	3,8

Turnover of organizations in the Leningrad region is showing positive trend as it increases 11% even in agricultural sector and equals 1.05 billion euros in 2015.

TABLE 12. Territories involved in agriculture (Petrostat, 2016)

Agriculture

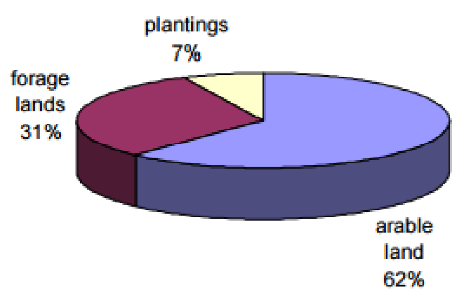
Land fund[1]

(end of the year, thousand ha)

	2012	2013	2014
Total land area	8531	8531	8531
Agricultural land area of farms	659	653	653
including:			
arable land	407	404	404
forage lands	208	204	204
perennial plantings	44	45	45

[1] Including land area in St. Petersburg, according to the data of the Federal Service for State Registration, Cadastre and Cartography (Rosreestr) in Leningrad region and St. Petersburg.

Structure of agricultural land area in 2014



The data regarding agricultural territories describes years from 2012 to 2014 and consistency in number of hectares involved. While there was a decrease by 3000 hectares of arable lands 1000 hectares more was obtained for planting perennial grass.

TABLE 13. Numbers related to agricultural production volumes (Petrostat, 2016)

Agricultural production at all types of enterprises
(thousand ton)

	2013	2014	2015
Meat (slaughter weight)	251	260	265
Milk	557	568	593
Eggs, million pieces	3170	3115	3080
Potatoes	296	285	322
Vegetables	253	263	253

Acreage in agricultural crops
(all types of enterprises, thousand hectares)

	2013	2014	2015
Total	231,4	226,8	229,9
including:			
grains	35,3	38,5	41,8
potatoes	17,2	16,2	17,0
vegetables	7,4	7,6	7,3
forage crops	171,3	164,0	163,4
industrial crops	0,2	0,5	0,4

Production per capita in St. Petersburg and Leningrad region (kg)

	2013	2014	2015
Meat (slaughter weight)	37	38	38
Milk	81	82	85
Eggs, pieces	464	449	441
Potatoes	43	41	46
Vegetables	37	38	36

A rather positive tendency can be seen in agricultural production as more milk, meat and potatoes were produced after the economic crisis began in 2014. The area involved in agriculture fluctuates and growth in territories is noted only in grain cultivation, while other products lost some lands during the last two years.

TABLE 14. Amount of farms and livestock population (Petrostat, 2016)

Peasant (farm) enterprises[1] (as of January, 1)

	2013	2014	2015
Number of registered peasant (farm) enterprises, thousand	7,4	7,3	7,3
Total area of farms, thousand ha	59,4	59,8	60,1
Average area of farms, ha	8	8	8

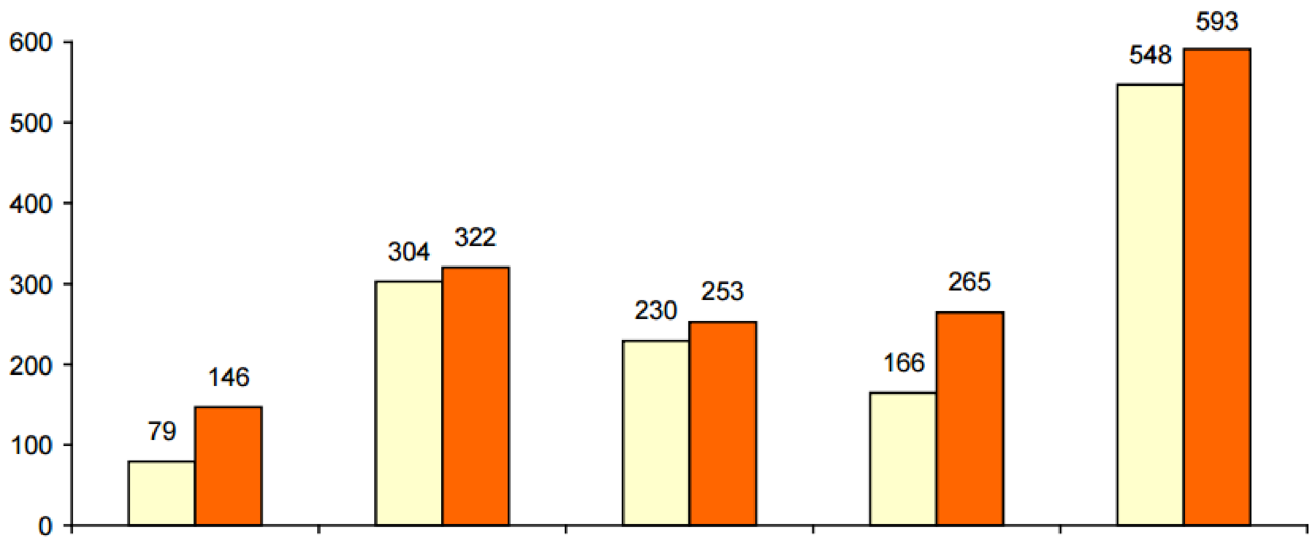
[1] According to the data of the Federal Service for State Registration, Cadastre and Cartography (ROSREESTR) in Leningrad region.

Livestock and poultry population by types of farms as of January 1, 2016
(thousand head)

	Cattle	including cows	Hogs and pigs	Sheep and goats
All types of enterprises	181,7	78,2	196,7	33,0
including:				
agricultural enterprises	164,3	70,4	188,8	4,9
peasant (farm) enterprises[1]	7,9	3,0	1,8	10,1
household plots	9,5	4,8	6,1	18,0

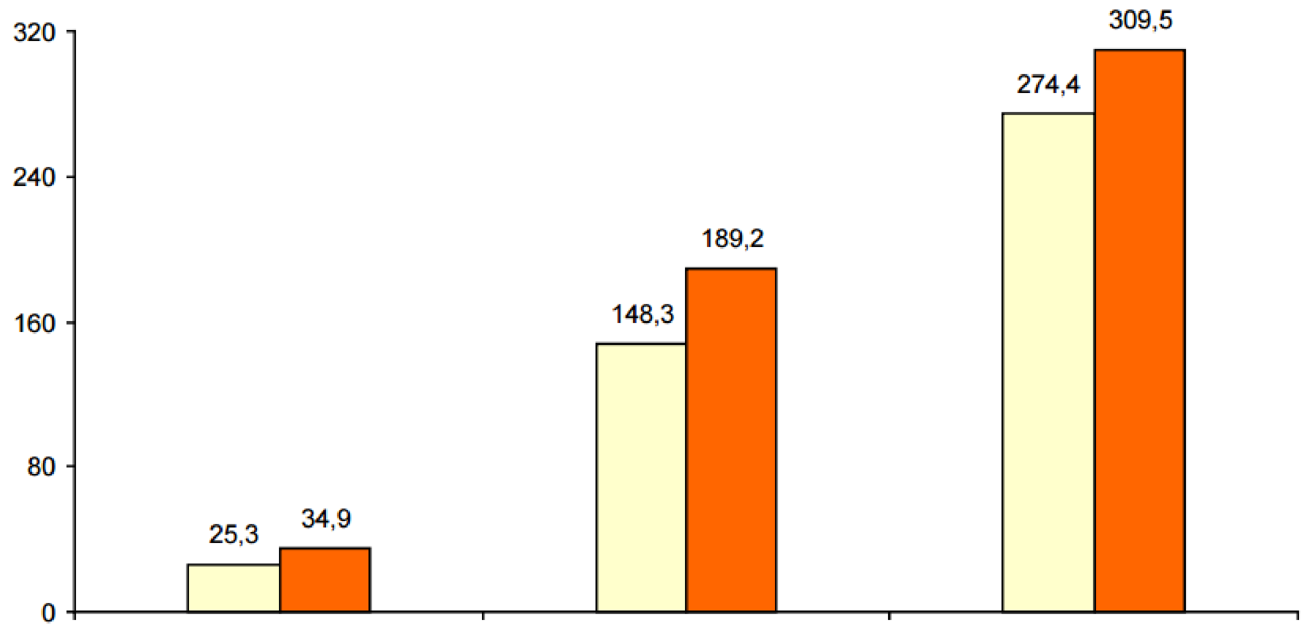
[1] Including sole proprietorships.

Federal Service for State Registration, Cadastre and Cartography is an organization to register companies and enterprises which noted a decrease of 100 farms since the crisis gained power. On the other hand, remaining farms increased their area by 700 hectares during this difficult period.



GRAPH 3. Dynamics of agricultural production in period 2010-2015 (Petrostat 2016)

Graph 3 shows the achievement of the Leningrad region farmers over the past 5 years regarding total harvest by categories of products measured in thousands of tons. Categories of products on Graph 3 from left to right are: grains and legumes, potatoes, vegetables, meat and dairy products. Russian government developed a support program for agriculture back in 2011 and results in weight of produced goods. There is a stable growth throughout all categories, especially grains and meat are experiencing rapid growth. Graph 4 below shows similar positive trend in harvest efficiency, for example farmers managed to collect grains by almost 1 ton more from each hectare due to proper fertilization, modern equipment and more quality crops. (Petrostat, Statistics of population, economy and agriculture in Leningrad region and Saint Petersburg, 2016.)



GRAPH 4. Yeild efficiency of grains, potatoes and vegetables 2010-2015 in centners per hectare (Petrostat, 2016)

To sum up, these graphics and tables represent how Leningrad region and Saint Petersburg are coping with difficult economic situation. Fall of the national currency – ruble, sudden drop of price of Russian main resource – oil, sanctions introduced by number of countries including Europe and USA and counter sanctions banning all key food products – all of these factors could damage a strong economy of any country. Saint Petersburg area was highly dependent on trade with European countries, especially Finland, so food product embargo was a very important factor in recent double price increase for all kinds of products. Since prices increased and salaries stayed at former level, people have less purchasing ability and tend to buy less expensive products. Quality of food on the market became an issue which is hard to control. All distributors had to urgently seek for new suppliers from third world countries while local food manufacturers cannot handle the demand. Crisis also affected businesses and organizations, there has been a trend to cut production costs and traditionally the easiest way is to reduce the number of employees. As a result – more than 4200 employees were fired in the agricultural sector of the region.

The situation is rather concerning but in general the region is handling the difficulties while the whole country is adopting to live in the new conditions. Oil market crisis is a positive event in the long run as Russia is finally making efforts to diversify its economy and produce own goods for local demand.

Development of agriculture is one of the key priorities government decided to support, there are several governmental aid programs including financing, privileges and investments. The Ministry of agriculture has a development plan for the period of 2013-2020 which was approved by Russian government on 14 July 2012 and includes following priorities:

- Development of import substitution program including support of vegetable, crop, meat and dairy producers
- Increasing profits of agricultural manufacturers
- Sustainable development of agricultural territories in order to keep resources and creation of products availability for population with low income
- Increasing production capabilities by using abandoned farming lands and introducing nutrients to make soils more fertile
- Development of integration networks, agricultural clusters by regions
- Formation of innovative agricultural complex
- Ensuring ecological safety of food production
- Increasing export volumes after satisfying domestic demand
- Minimizing logistic costs and optimizing rational deployment of new farms by regions

Budget funds allocated for agricultural complex in 2016 is 237 billion rubles or approximately 3,6 billion euros. Also in 2015 the amount of budgeted money spent for agricultural program increased by 19% compared to 2014, significant part of this support was spent on coverage of bank loans and credits. This program allowed to decrease import of products by 33.6% compared to 2014. However, export of agricultural products decreased by 14.8% in 2015 with wheat having 3.8% decrease. To manage this issue government created such institutes of export development as Russian insurance agency of exporting credits and investments, ROSEKSIMBANK and Russian exporting center. Another group of experts was created of leading exporting manufacturers, representatives of associations and unions. Main mission of the group is promotion of Russian agricultural products on key export markets. The result of agricultural program by the end of 2015 shows that 6 development targets were reached, while indexation of food and physical volume of investments as well as rising amount of high skilled workplaces could not be implemented.

The number of greenhouse farms dropped by 1.7% compared to previous year, but the area of winter greenhouses increased by 2000 hectares. Main reasons of slow growth of greenhouse farms are cheap imported vegetables, higher increase in prices on gas and electricity than on vegetables. (National report on progress and results of governmental program of support for agricultural industry 2013-2020, Ministry of Agriculture, 2015.)

Decrease of investment activities was caused by uncertainty in national macroeconomics and increased costs of loan sources which led to needs of additional budget spending. Time will tell if the Russian government is capable to diversify economy, introduce structural reforms and manage economic isolation, but for now it is capable to avoid critical situations and shortages of food.

The need for Russia to raise and maintain high efficiency of agriculture along with efforts of society and government to improve ecological climate by implementing waste recycling system (particularly in Saint Petersburg) is a good environment for TraceMix fertilizer and Rec Alkaline battery recycling technology.

4.2 Customer base

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Important to notice, the region is not oriented on agriculture as much as South and Central Russia due to cold climate and poor soils. Despite that, Leningrad region produces 41.4% of crops within North-West of Russia and contributes just 2% of total crop production in Russia.

Based on the data in the end of 2014, the agro-industrial complex of the Leningrad region consists of 526 large and medium enterprises with various forms of ownership. Among these organizations there are 256 agricultural enterprises, 10 feed mills, 113 enterprises of food and processing industry, 147 enterprises of fishery industry. The region also has 5 agricultural consumer cooperatives, nearly 1 000 peasant (farmer) households and more than 104 000 of small private farms.

Farmers of the Leningrad region are constantly looking for cost-efficient methods to increase yield collected from each hectare, therefore their interest in micronutrient fertilizers is natural. Majority of farms are already applying wide range of fertilizers including macronutrients, micronutrients and plant protection agents. The results of my contacts and conversations with agricultural organizations will be described in the last part of the thesis, while Rec Alkaline was contacting farmers on the issue of micronutrient fertilizer demand in spring of 2016. Most of agronomists and representatives expressed interest regarding the product, ask for additional information, certain content description, results of tests and experiments, its efficiency on different types of plants, references on scientific researches and so on. Naturally, information should be provided in the Russian language.

Some farms were not interested because of the specific technologies and micronutrients are already used in their production and proven efficient. Typically, if a process is well-established and brings profits Russian people are hard to convince to risk and invest into new methods and tools.

In general, there is a broad customer group in densely-populated Saint Petersburg and agriculturally active Leningrad region which could be reliable clients in case of proper marketing, description of advantages and involvement of battery recycling aspect of production technology.

4.3 Competitors

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4.4 Product's potential

To evaluate opportunities of TraceMix on the Russian market, it is helpful to analyze data regarding amount of different types of fertilizers for various plants used by farmers in Leningrad region in 2015.

TABLE 20. Application of mineral and organic fertilizers for harvesting in 2015 (Petrostat, 2016)

	Applied for agri-cultural crops in total	Cereals (except maize)	Wheat	Potatoes	Vegetables
Nitrate fertilizers, cent-ners	52021	11096	3105	1927	1920
Phosphate fertilizers, centners	11477	6026	1280	1772	839
Potash fertilizers, cent-ners	18316	5736	1280	4425	3132
Mineral fertilizers kg/hectare	42	59	76	217	260
Area treated with mineral fertilizers, hectares	93084	24463	5165	2988	2007
In percentage to total seeding area	48.3	63.3	69	79.8	88.5
Organic fertilizers, tons	1739300	614907	84687	78905	136513
Organic fertilizers, tons/hectare	9	15.9	11.3	21.1	60.2
Area treated with organ-ics, hectares	33978	12975	2520	1276	1150
In percentage to total seeding area	17.6	33.6	33.6	34.1	50.7

The Table 20 illustrates that fertilizers are in active use in Leningrad region, especially NPK and Organic fertilizers, such as chicken and cow manure. Unfortunately, there is no statistical data regarding use of micronutrients. Russian farmers are rarely using micronutrients and there is small competition on the market. Efficiency of micronutrients has to be better promoted and be economically viable for farmers.Overall demand of fertilizers on the Russian market has increased by 20% in 2016. Despite the fact, prices on the market remain low. Standard & Poor predicts that prices will be lower than in 2015 for several years onwards and it will lead to smaller profits of fertilizer manufacturers. Russian fertilizer producers will be able to compensate losses by growing demand and weak national currency. Prices in rubles for fertilizers increased from 1% on ammonium nitrate to 27% on potassium chloride. (Ministry of agriculture.)

Some companies were experiencing difficulties in 2015. “Uralkaliy” decreased production by 6% and sales went down by 9% comparing to previous year. Potassium demand globally dropped by 3-4% but general director of “Uralkaliy” keeps optimistic approach to long-term perspectives of the industry. Important to notice this manufacturer is providing a discount of about 20% on their products for Russian farmers compared to export prices because of government needs to support local agriculture.

The Ministry of agriculture is planning to increase seeding areas by 350 000 hectares in 2016 what will equal to additional 15-20 million tons of crops. That will lead to natural increase in demand of fertilizers and the only factor blocking the growth is the purchasing ability of farmers who have to take bank loans with higher interest rates. (Nagornyh, 2016.)

5 PRACTICAL WORK

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6 CONCLUSIONS

First of all, I would like to express gratitude to the Rec Alkaline company and specifically Development Director Jarmo Pudas for this great opportunity to experience business life and learn an enormous amount of information about battery recycling, the fertilizer industry, environmental impact and international business. I felt great motivation to continue working in this industry as its raw material is contaminating our planet and the final product is solving the problem of hunger and limited area for agriculture. This is technology of the future and its impact on environment will be appreciated decades after. It was very important to study what a great positive impact micronutrients have on the health of plants, humans and even soil. I hope the theoretical information provided in this thesis will help people to realize the importance of proper plant cultivation as well as protection of environment from battery pollution.

It was especially interesting for me because the company is considering the Russian market and it is always an honor to help your motherland in issues of caring about nature and food cultivation. As analyzed during market research, Russia is facing severe economic crisis in recent years and developing local agriculture is a top priority for the government. Russian farmers have not yet fully realized the importance of micronutrient application but with proper advertisement and involvement of government this problem might be solved in the nearest future. At this time, it is crucial to enter the market having reliable partners with established sales and logistic channels.

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