The use of peat as a raw material for chemisry today and in the future

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Introduction

The technologies of peat chemistry have resulted in ten categories of products which are used in different branches of industry, agriculture, medicine, cosmetics, polygraphy and others. The most frequently used of these are peat biostimulators for plants, animals and microorganisms; adsorbents for water and gas purification and for the breakdown of oil and oil products which have overflowed from the water and soil surfaces; as well as products for home chemistry, building materials, medicines and cosmetics.

Despite the number of products produced from peat, the quantity of peat used for chemical processing comprises not more than 1% of the total amount of peat extracted in the world. The basic uses for peat still remain those for energy, agriculture and horticulture. However there is an increasing demand for the products of peat chemical processing arising from global climate change, increasing environment contamination, depletion of nonferrous and other metal deposits, the building of new nuclear power stations and the closing down of those that have become obsolete, as well as the demands of a resource economy. Obtaining products to meet these needs is possible due to a number of peculiarities and advantages of peat in comparison with other types of organic raw material.

Advantages of peat

The first of these is the influence of natural factors on the chemical composition and physical structure of peat: relief, hydrothermal coefficient, mineralogical and chemical composition of rocks surrounding and underlying the peat deposits, composition of ground water, oxygen regime and others. These factors influence the botanical and biochemical composition of peat- forming plants and the direction and intensity of the processes of their transformation under mire conditions. Besides the components of peat-forming plants, a major role in the creation of the chemical composition of peat arises from: humic substances, which are absent in living plants, compounds of microbial origin and substances carried by underground waters and with precipitation.

A second peculiarity is the exceptional complexity of chemical composition and physical structure of peat. The many variations of combinations of natural factors result in a wide diversity of peat types, differing by botanical composition, degree of decomposition, chemical composition of mineral and organic components, porosity and pore sizes, absorption ability, biological activity, ion exchange properties and many others. This variety provides a rich choice of peat raw materials for the chemical industry.

A third peculiarity is the dependence of the chemical composition of peat raw material on the method of peat extraction and the duration and conditions of its storage. For instance, a minimum two years is required from the beginning of peatland drainage until the storage of the first stockpiles if the milled method of peat extraction was used. The significant changes in the peat in drained peatlands take place during this time under the influence of the oxidation-reduction processes, fermentation and other biochemical reactions. Equally great changes take place in the chemical composition of the peat during storage in stockpiles, especially if milled peat has been subjected to self-heating.

The next relevant feature is the irregularity of the deposition of peat strata throughout the depth within a single area of peatland. The degree of regularity of the historical development of peat deposits is linked to changes in water and mineral inputs and to periodic climate changes while the peat deposits are forming. During this process the botanical composition of peat forming phytogenesis and the chemical composition of the peat are changed correspondingly. For this reason peat deposit profiles often look like ‘flaky pie’, and this subsequently creates problems for the extraction of peat raw material with a uniform chemical composition. Specialists are therefore have to use special technical equipment in order to average the composition of the excavated peat by mixing peats from the full depth of the deposit.

Absorbents and adsorbents

The production of absorbents and adsorbents is one of the most rapidly developing branches of peat chemistry today. It is necessary to note that the sorption properties of peat and its components are determined by a well-developed porous structure and the presence of a wide diversity of functional groups, which are able to facilitate donor-acceptor interactions, ion exchange reactions and the creation of hydrogen ties. These characteristics depend on the type, kind, degree of decomposition, ash content and pH value of the peat; the depth of the stratum layer, the method of extraction, and the conditions and duration of storage of the peat. Chemical, physico-chemical, thermal and biochemical peat processing makes it possible to obtain a wide range of products with specified sorption properties for environmental protection, medicine, the food industry, the mining of minerals and the deactivation of radioactive contaminations.

The solid sorbents for the purification of water from heavy metals and radioactive substances as well as from concentrations of nonferrous metals, for example from sewage, are prepared from highly decomposed peat of the high moor type, enriched with functional groups. The liquid water soluble coagulants of metals from different solutions are produced from highly decomposed peat of different types but with low ash content.

On the other hand, for the removal of oil from waters and soils the sorbents are produced from weakly decomposed peat of high moor type with a highly developed porous structure independently of the content of functional groups. Sorbents with increased sorption capacity for oil floating in water are produced by modifying peat raw material with surface-active agents. Biosorbents for accelerated oil decomposition in waters and soils are obtained by a combination of chemical and microbiological modifications of peat. Such bio-sorbents allow for the decomposition of up to 100% of aliphatic and 80-90% of aromatic carbohydrates in the arable layer of soil during one vegetation season. Soil can be completely cleaned from oil contamination over a period of two years by the application of peat-based bio-sorbents.

Activated carbon

Thermal processing in combination with chemical modification of peat makes it possible to obtain a wide variety of activated carbon with specific pore sizes including molecular-sieve properties for the purification of gas and liquid mediums. Very pure and safe varieties of activated carbon are produced for medicine, the food industry and wine-making. Comparatively cheap varieties are produced for use in the chemical industry (for example, when producing synthetic fibres) and for the final cleaning of industrial waters. The technologies of sorbent producion in the form of fibres has been developed using the fibrous part of peat instead of rather expensive synthetic ingredients. The best raw material for activated carbon production is peat with a low ash content.

Decontamination

The Chernobyl catastrophe has given a powerful impulse for the creation of cheap peat-based means of and technologies for the deactivation of metallic surfaces, waters and land areas. Some types of peat are able to absorb up to 50 mg/g of strontium, 105 mg/g of cesium or 160 mg/g of uranium. Preparations for the deactivation of technological equipment on the basis of humic substances in highly decomposed peat were created.

Ion exchange and binding properties of peat humic substances have been successfully used for developing additive agents to geo-technological solutions destined for the extraction of non-ferrous metals, rare and diffused elements by piled and underground leaching.

Peat dyes

The existence of developed system of polyconjugation in molecules of humic acids gives a specific basis for the creation of a technology to produce peat dye for timber furniture, natural and synthetic fibres, paper, drapery, leather and other substances. Peat dye is better than its synthetic analogues in color and in light resistance properties. Highly decomposed peat of the high moor type is the best raw material for producing peat dye.

Medicine and cosmetics

The chemical treatment of peat for medicine, cosmetics, balneology and veterinary medicine is based both on the structural peculiarities of the peat raw material and the biological variety of peatland vegetations. More than 50 herb varieties grow on peatlands and are part of the peat formation processes, including: *Comarum palustre*, *Menyanthes trifoliata*, *Valeriana officinalis*, *Ledum palustre*, *Oxicoccum quadrifolia*, as well as many species of the families *Salicacea*, *Pinacea*, *Betulacea*, *Sphacea*, and their biologically active substances are accumulated in peat. Some of the biologically active substances are lacking in living plants but are produced in the course of the peat formation process.

Although the chemical industry for producing products for medicine and cosmetics is in its infancy, a number of natural preparations from peat are already well known, for example, preparations for the medical treatment of psoriasis, herpes and eye diseases; for accelerated healing of wounds and the inosculation of nervous fibres after surgical operations; natural steroid preparations; cosmetics for eyelashes and for the removal of wrinkles leading to a healthy and velvety skin; preparations for hair strengthening and the slowing of baldness; the treatment of dandruff; hand cleaners; bath preparations which provide general strengthening and medicinal action; and, finally, a number of preparations for the treatment of animals. Preparations have also been developed possessing anti-tumor and anti-virus activity. The chemical modification of medicinal mud with sodium bicarbonate enriches the mud solution with biologically active substances and makes it more efficient.

The industrial production of all these preparations requires a careful choice of raw material whose characteristics should include not only of general technical properties, but also a wide range of other properties such as chemical composition, organic and mineral compounds, including specific medicinal properties. Only certain types of peat have so far been fully investigated. The production of chemicals from peat for use in medicine, cosmetics, balneology and veterinary medicine has a great future, because the application of 'soft' technological regimes without changing the molecular structure of the natural compounds results in a 'naturalness' of the resulting preparations, and the raw material basis is unlimited. The creation of a controlled process of extraction of medicinal peat by through the cultivation of the necessary varieties of medicinal plans and their controlled humification will be possible in the near future.

Agriculture

The chemical processing of peat for agriculture is carried out in small- and large-scale variants. Small-scale processing includes the manufacture of humic growth regulators; humic fertilizers with microelements, in which humic substances carry out a role of biologically active binders; and also natural ecologically clean means for the protection of plants from diseases both at cultivation and during storage. For the manufacture of these latter materials the types of peat used contain such strong antiseptics as sphagnol, tannins, terpenes, tars and waxes. For the manufacture of humic bio-stimulators, different types of peat are used with a high and medium degree of decomposition.

Some of the newest developments include the creation of special humic preparations for structuring sand and preventing its movement by wind. The application of such preparations on the edges of roads which cross areas of desert sand can bring major economic and ecological benefits with a very small input of peat raw material.

The large-scale chemical processing of peat for agriculture is carried out to produce universal soil ameliorants of long action (ten years), which are especially effective in combating the degradation and desertification of agricultural lands. These ameliorants can also be used in the cultivation and afforestation of existing deserts. Such ameliorants are required for the countries of Africa, the Middle East, Central Asia, and desert areas of China. The application of the above-mentioned ameliorants allows for the radical improvement of such important soil properties as its structure, and water-physical, agro-chemical, biological and biochemical activities. Their application can assist in raising the fertility of agricultural lands, restoring degraded soils, and the development of desert sand areas for agriculture and for the planting of trees and gardens. The planting in this way of large man-made forests can greatly improve the conditions for vegetation and animal biodiversity, and provide more comfortable conditions for millions of people residing in arid and semi-arid zones. In the context of global warming, such important changes in agriculture and forestry through the use of these soil improvers could reduce the number of climatic refugees and the number of local conflicts resulting from displacement.

Rehabilitation of soils

The preconditions exist in European countries for an increase in the manufacture and application of special ameliorants for the ecological rehabilitation of soils polluted by heavy metals and organic pollutants. Such ameliorants have the ability to convert heavy metals into strong fixed forms, inaccessible to plants, as they are included in the structure of the crystal lattices of clay minerals and make possible ecologically clean production on the polluted soils. Such areas are found on the outskirts of all large European cities and they grow in extent all the time.

Future requirements of peat for agriculture

According to some expert estimations, the total peat raw material requirement for the production of universal and special-purpose soil ameliorants should rise to over one hundred million tonnes per year. Future requirement for these products will increase arising from global warming and the intensification of anthropogenic influences on the environment. Those approximate quantities of peat are already used annually in the preparation of traditional organic fertilizers for the maintenance of a sufficient humus balance in agricultural lands in many countries of the world, including large areas of the Russian Federation.

Sapropel

This total requirement of extracted peat could be reduced by 30-40 of % by replacing it with sapropel, a natural organogenic fresh-water lake sediment.

The extraction of peat generally destroys the ecosystems of mires but the excavation of sapropel, on the contrary, improves the ecosystems of lakes filled with silt. The future would appear to lie in the development of complex ameliorants including sapropel as a substitute for peat. On a world-wide basis, the volumes of peat-based ameliorants for the creation of favorable conditions for plant cultivation on desert sand territory could be greatly increased by including sapropel. The valuable properties and favorable qualities of sapropel for agriculture will be recognised in many countries in the near future. It therefore it seems reasonable for the International Peat Society to stimulate further study on sapropel use, as the process of sapropel sediment accumulation is often is the first stage in the formation of peat deposits. The natural properties of sapropel present as many opportunities for chemical processing as does peat.

The structure and properties of sapropel differ depending on its origin, type and variety. On these depend the opportunities for the selection of the appropriate sapropel raw material for the required purposes. Careful selection of peat and sapropel varieties allows the "design" of composite ameliorants, characterized by their natural origin, and having the appropriate properties to assist with the creation or restoration of forest- or crop-bearing soils.

It is an indispensable condition for this work that the sapropel raw material should be ecologically clean. The age of sapropel deposits with a potential for industrial use, surrounded by forests and situated not less than 10 km from cities, roads, enterprises etc. in Belarus, for example, is between 3-10 thousand years. This guarantees the ecological cleanliness of this sapropel raw material.

When creating ameliorants it is particularly important to take into account the ratio of precipitations to the average temperatures (hydrothermal coefficient of the area). This predetermines the intensity and character of the transformation of the organic substance, its interaction with mineral soil components and the availability and metabolism of nutrient elements in the agro-ecosystem. Thus ameliorants developed for use in a humid zone are unsuitable for application in arid zones, as this would inevitably result in the accumulation of undesirable products in the arable layer of the soil and would suppress plant development. The compositions of ameliorants for arid, semi-arid and humid zones are essentially different. It is for this reason that the careful selection of peat, sapropel and other raw materials is so important. This selection should be based on the structure and properties of the organic substance; the presence of organic-mineral colloidal particles; mineral composition - contents of Ca, Fe, Mn, S and reaction of medium. Failure to take into account soil-climatic conditions and the characteristics of different kinds of raw materials will lead to negative results in developing an international market for ameliorants.

Granulated Organic-Mineral Fertilizers (CGF)

The expansion of the manufacture and application of complex granulated organic-mineral fertilizers (CGF) based on peat and sapropel is promising prospect for modern agriculture and environmental protection. The use of mineral fertilizers, as is well known, has significant ecological and agronomical downsides, as in large doses they suppress soil biota, have a stressful influence on plants; pollute ground waters and agricultural produce; transform soil humus into a water-soluble state; and destroy agronomically valuable soil aggregates. This results in reduced permeability, a worsening water-air regime and the occurrence of soil swelling.

There are also economic, practical and ecological restrictions on the application of organic fertilizers in significant doses due to the resultant imbalance in nutritious elements and the expense of transporting them over large distances.

The creation of CGFs offers an appropriate solution to the agronomical, ecological and economic problems outlined above. These latter fertilizers, on the one hand have the same properties as mineral fertilizers for the proper supply to plants of nutritious substances, and on the other, organic fertilizers have the properties to reduce the negative effects of high concentrations of mineral salts. CGFs are characterized by slow-release nutrients and are especially effective on soils of light granulometric composition particularly in irrigation conditions such as in irrigated agriculture and the cultivation of rice. These fertilizers are ecologically compatible; have a balanced composition; and contain humic substances. They also contain natural hormones and other natural plant growth- and development-regulating substances. They avoid the pollution of soils and ground waters by chemical substances. In comparison with the separate application of organic and mineral fertilizers CGFs are characterized by their synergistic effect, which results not only in higher crop yields, but also improves quality and biochemical values.

Conclusion

Science is already to-day able to offer to customers this and other products of peat chemistry. An adaptation to peat chemistry of new ecologically safe technologies, for instance, treatment by cold plasma, mechanic-chemical impaction and photolyse is in perspective. This may result in the creation of enterprises with waste-free chemical production based on peat, when the waste from the production of one product is the raw material for the production of another.

A prognosis for the development of the peat-chemical industry shows that taking into account an inevitable decrease in peat consumption for energy and the replacement by sapropel of a large proportion of the peat used in the production of soil ameliorants and organic fertilizers, the share of peat used in peat chemistry will grow from 1 to 10–15 % of total peat extraction in the next 20 years.