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THE EFFECT OF METALS ON THE SURVIVAL OF SAPROPHYTIC MICROFLORA ORIGINATED FROM UPPER-TISZA AND SZAMOS RIVERS IN LABORATORY CONDITIONS

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Abstract
The aim of our paper is to obtain more and better information on the ecological and microbiological status of the inundation area of the Upper-Tisza River in both the Hungarian and the Ukrainian region. With these proper data we shall be able to reach the objectives of our work: conservation of the natural resources and values of the cross border region in order to provide and utilize possibilities for common environmental problems with cross border effects in order to protect surface and sub-surface waters, improve water quality, and effective prevention and environmental management of pollutions related problems both Tisza and Szamos Rivers.

Therefore we were studied from 2004 to 2007 years in the body of Tisza and Szamos Rivers the changing of saprophytic microflora on the influence of heavy metals in laboratory experiments. We determined the pH, temperatures, heavy metal contents and total number the saprophytic micro-organisms (sampling sites: Rahó, Milota, Vásárosnamény, Dombrád, Csenger) different places in water. We used cultures media (Nutrient, Malata, Yeast, and Mc Conkey agars), biochemical and API (Bio-Meriux) tests, and heavy metals (Cd, Cu, Zn, Pb). The experiments were in 24 and 48 hours and 50, 100, 500 and 1000 mg/kg metals we used. In Tisza and Szamos Rivers the main micro-organisms species to survive the 1000 mg/kg metals (Cd, Cu, Zn, Pb) were: Aeromonas salmonella salmonicida, Agrobacter radiobacter, Candida humicola, Candida inconspicua, Candida lambica, Cryptococcus laurentii, Cryreomonas luteola, Flavobacterium indologenes, Flavobacterium meningosepticum, Neisseria ssp., Pasteurella ssp., Pseudomonas chlororaphis, Pseudomonas vesicularis, Rhodotorula minuta, Trichosporon cutaneum, Trichosporon pullulans, Vibrio metschnikovii, Sphingomonas paucimobilis.

Along the Tisza River the saprophytic microflora was changing and the Szamos saprophytic microflora effects the Tisza water body.

Key words: water, metals, bacteria, yeast, pollution.

INTRODUCTION

In the catchments area of Upper-Tisza there can be found 10 industrial by-product/waste reservoirs. Altogether there are 43 outlet sources which are surface water pollutants or could be potential pollutants. Although Tisza as a surface watersource is regularly get polluted, until recently it have not reached the pollution level of water sources of developed industrial areas and it was eliminated by the regenerating and reproducing capacity of the river. The Upper-Tisza River popularly and in effect and can be considered as clean-water and close to natural condition.

In the last ten years there were many serious natural disasters such as flood, cyanide and heavy metal pollutions with great ecological effect in the catchments area of the Tisza River, which adverted to the reviver and the preservation of its environment.

In 2000 the cyanides and heavy metal pollution, occurred almost in succession, increased the number of studies on biocoenoses. Previous to this pollution, there were not such comprehensive analytical examinations in the Upper-Tisza region, which certain effects of the pollution could be correlated to. Thus the contributions to knowledge and data resulted after the pollution, can be regarded as basic/raw data, and have extreme importance for the future.

In 2000 years, large amount of mud polluted with 20 000 tons of heavy metals got into the River Tisza through the River Viso. According to assumptions, the mud contained approximately 50 tons of lead, 20 tons of copper and 70 tons of zinc mainly bound to suspended materials/loads. (The lead being bound to the suspended load reached 1500 mg/kg value, the copper 900-1100 mg/kg, the zinc 1400-1500 mg/kg at Tiszabecs). The metals were mostly zinc (Zn), lead (Pb), copper (Cu) and highest cadmium (Cd) concentration from the conventional level.

Zinc is a widely used heavy metal and concentrations of total zinc in European rivers range from micromoles per litre to near hundred micro-millimoles per litre in the most polluted ones (Whitton et al., 1982). Long-term effects of zinc on microbenthic communities have generally been reported at concentrations ranging from 0.05 mg to 2.5 mg /l (Dean-Ross, 1990; Niederlehner and Cairns, 1992, 1993; Loez et al., 1995). Not all metals are equally reactive, toxic, or available to biota (Hare, 1992). In fact, measurement of total metal ion concentration in solution is often meaningless for prediction of metal behaviour (Campbell and Tessier, 1989). Rather, the free ion form is thought to be the most available and toxic (Martell et al., 1988; Shuttleworth and Unz, 1991; Campbell, 1995).

Moreover, the mud certainly contained other heavy metals having much more dangerous effects on the biocoenoses. According to the Hungarian standards, the quantification of the metals is applied only to solutes, and does not contain the metals being bound to suspended loads, which have much more dangerous effects on the biocoenoses in the long run.

We have done the examinations according to given aspects on determined spots of the Upper-Tisza, regarding the preservation of values as primary aim. On the basis of the fact above, the main objectives of the project are the following:

Our goal in this paper is the examination of eco-toxicological effects of different pollutions on the biocoenoses of waters. Our aim was to the implementation and evaluation of basic experiments on the change of quantity and quality of saprophytic bacteria. We want to examination of the resistance of micro-organisms against polluting materials, the mobilisation, immobilisation, accumulation and transformation of the pollution.

The saprophytic bacteria in natural water are important members of microbial communities with environmental and economic interest. Heavy metals are generally toxic for micro-organisms including saprophytic bacteria, blocked the functional groups of important molecules such as enzymes.

The potential effects of toxic compounds in the environment are determined not only by their intrinsic toxicity and concentration but also by their physico-chemical forms. Whereas the total metal concentration is easier to measure, it is not a reliable indicator of toxicity (Campbell, 1995). The availability of an element to living organisms depends on its chemical speciation.

In natural water systems, trace metals can be partitioned between different physical states such as free or complexed, associated with colloids or with particles. It is often assumed that metals are mainly bioavailable in free ionic and labile form for micro organisms (Tessier and Turner, 1995), whereas the particle-bound or ligand-complexed metals are viewed as not directly available for micro-organisms (Campbell, 1995). In this context, toxicity bioassays with micro-organisms can be useful tools to link the biological response with chemical speciation in natural waters (Stauber et al., 2000).

Many authors found that potentially metal-tolerant organisms in water are *Pseudomonas* sp., *Sphingomonas* sp., and *Bacillus* sp. (Jackson et. al. 2009).

Pollution by metals and microbes (Pegram et al., 1999), amongst others, greatly influences the quality of the water sources, and leads to the continued search for new and improved methods to not only clean up contaminated systems, but also to achieve this aim in an environmentally friendly waters.

In aquatic systems, the bioavailability of an element to micro-organisms is greatly influenced by its chemical speciation. The metal toxicity to green algae (*Pseudokirchneriella subcapitata*) and a bacterium (*Vibrio fisheri*) may be as a function of size fractionation and chemical speciation in contaminated water (Guéguen et al., 2004).

During the last fifty years the utilization of antimicrobial drugs has steadily increased. Antimicrobials are extensively used in human medicine to treat or prevent bacterial infectious diseases. In addition to the large use for the treatment of human illnesses, antimicrobials are commonly used in veterinary practices. Antimicrobial shave also been used for years at subtherapeutic concentrations as growth promoters in animal husbandry, as it allows the increase of the animal weight without increasing the food ration (Nwosu, 2001).

Servais and Passerat in 2009 studied the antimicrobial effect of fecal coliforms bacteria originated from Seine River. At the global scale of the Seine river watershed, domestic wastewaters seemed more likely to be the predominant source of the antimicrobial resistance of fecal bacteria found in the rivers. This was corroborated by the similarity of the multiple antimicrobial resistance indices from river and municipal waste water isolates for both fecal indicators.

MATERIALS AND METHODS

Sampling

In case of water samples were collected from seven sampling sites along the Tisza (6) and Szamos (1) Rivers. Three sampling points was marked out on each sampling sites. Samples were taken from three places of a given water median. The three samples which were taken from the same depth was mixed with each other.

Methods

After mixing the samples, we isolated the bacteria and yeasts from them, and repeated isolation three times. From the water dilutions, 100 μl were spread over the surfaces of Nutrient, Mc Conkey, Malata and Yeast culture-media. After 48 hours-long incubation on 26 ^{o}C, the bacterium colonies were counted and morphologically different colonies were isolated. For the evaluation, we used the number of colonies in 100 μl water and determined the number of bacteria (yeast) in 1 m^3 (CFU/m^3). Separation of bacterial genera was carried out on the basis of colony morphology, Gram's stain, (Hucker 1922), spore stain (Bartholomew et al., 1950), oxidase-reaction (Kovács, 1956), catalase-reaction and metabolism of glucose (Hugh et al., 1953), while species were identified with API (bioMeriux, France) identification test. Total heavy metal content as well as the content of available heavy metals in water samples was determined by analysis of Cd, Cu, Pb and Zn after acid digestion, using inductively coupled plasma mass spectrometry (ICP-AES).

The metal tolerance were carried out 24 and 48 hours on 26 ^{o}C at 50, 100, and 1000 mg/kg metal in 1 kg water.

RESULTS AND DISCUSSION

For measuring the present state we had four places of sampling on River Tisza (Rahó, Milota, Vásárosnamény, Dombrád) and one place of sampling on Szamos (Csenger).

On the basis of the research to be carried out, there will be suggested new efficient and inexpensive matrix modifiers enabling to carry out operative control of water quality regarding content of heavy metals and saprophytic microflora, without preliminary sample preparation.

Investigation field is ecological monitoring and protection of environment, first of all the source of natural and Water Rivers.

The table 1 shows the average value of pH, temperature and metals concentration of rivers. The changes of pH along the Tisza River are raised. It looks like root cause the changing of pH the Szamos River, join with Tisza at Vásárosnamény. Temperatures between 20-27 ^{o}C and metal concentrations (Cu, Zn, Pb, Cd) were below the demonstrability.

Table 1. The pH, temperature and metals concentrations on the sampling places along the Tisza and Szamos Rivers

Sampling place	pH	Temperature ^{o}C	Metals			
			Cu	Zn	Pb	Cd
Tisza	7.56	20	< 0,01 mg/l	0,01 mg/l	< 2 µg/l	< 0,6 µg/l
White Tisza	7.52	20	< 0,01 mg/l	0,01 mg/l	< 2 µg/l	< 0,6 µg/l
Black Tisza	7.36	20	< 0,01 mg/l	0,01 mg/l	< 2 µg/l	< 0,6 µg/l
Milota	7.62	20	< 0,01 mg/l	0,03 mg/l	0,6 µg/l	0,0 µg/l
Vásárosnyamény	8.62	26	< 0,01 mg/l	0,01 mg/l	< 2,0 µg/l	< 0,6 µg/l
Dombrád	9.03	27	< 0,01 mg/l	< 0,01 mg/l	< 2,0 µg/l	< 0,6 µg/l
Szamos (Csenger)	9.1	20	0,05 mg/l	0,08 mg/l	3,0 µg/l	< 0,6 µg/l

Campbell 1995 shows that the effects of toxic compounds in the environment are determined by their physicochemical forms and. the availability of an element to living organisms depends on its chemical speciation.

Our result shows that the low concentration of toxic compounds as metals (Cu, Zn, Pb, Cd) did'nt generate the decrease of bacterial and yeast flora (table 2). The compounds of bacteria, yeasts, and coliforms bacteria depend on the human contaminations mainly the sewage waters which are without purifying the rivers.

As Pegram et al. (1999), results shows that the water pollution by metals and microbes, greatly influences the quality of the water sources, and the aims to achieve this aim in an environmentally friendly waters. We found that the number of total bacteria changes between $2.47x10^{9}/m^{3}$ - $8,81x10^{9}/m^{3}$ and yeasts changes between $0.7x10^{5}/m^{3}$ - $3.25x10^{6}/m^{3}$. We found coliforms pollution in Szamos River and this bacterial community effect the compounds of microbial population of Tisza.

Table 2. The total number of saprophytic microflora on the sampling places along the Tisza and Szamos Rivers

Sampling place	Total number of bacteria	Total number of yeasts	Coliforms
Tisza	$2.47x10^{9}/m^{3}$	$0.7x10^{5}/m^{3}$	0
White Tisza	$2,47x10^{9}/m^{3}$	$0.7x10^{5}/m^{3}$	0
Black Tisza	$2,47x10^{9}/m^{3}$	$0.7x10^{5}/m^{3}$	0
Milota	$2,47x10^{9}/m^{3}$	$0.7x 10^{6}/m^{3}$	0
Vásárosnamény	$3,5x10^{9}/m^{3}$	$1.7x10^{6}/m^{3}$	$0,6x10^{7}/m^{3}$
Dombrád	$8,81x10^{9}/m^{3}$	$2.7x10^{6}/m^{3}$	$1x10^{7}/m^{3}$
Szamos (Csenger)	$7,10x10^{9}/m^{3}$	$3.25x10^{6}/m^{3}$	$3,8x10^{9}/m^{3}$

In 2000 years, large amount of mud polluted got into the River Tisza. The lead being bound to the suspended load reached 1500 mg/kg value, the copper 900-1100 mg/kg, the zinc 1400-1500 mg/kg (at Tiszabecs). The metals were mostly zinc (Zn), lead (Pb), copper (Cu) and cadmium (Cd) concentration highest the conventional level. Our laboratory experiment shows (table 3 and table 4) that the 50 and 100 mg/kg metals decrease the number of bacteria in water relatively high rate. Our outcomes correspond Martell et al. (1988), Shuttleworth and Unz (1991), and Campbell (1995) results that the free ion form is thought to be the most available and toxic, and contradict to Campbell and Tessier (1989) that the total metal ion concentration in solution is often meaningless for prediction of metal behaviour.

The 500 and 1000 mg/kg of studied metals were more toxic the bacterial flora between Upper-Tisza (Tisza, White and Black, Milota) than at Vásárosnamény, Dombrád and Csenger. It looks like that the Szamos microflora were more dominant the survival of bacteria and were more resistant the toxic effect of high concentration of metals. The studied metals toxicity on the bacterial surviving were Cd >Cu >Pb >Zn.

According to Guéguen et al. (2004) in aquatic ecosystems, the bioavailability of an element to micro organisms is greatly influenced by its chemical speciation. The metal toxicity to bacterium may be as a function of size fractionation and chemical speciation in contaminated water. Jackson et. al. (2009) found that potentially metal-tolerant organisms in water are *Pseudomonas* sp., *Sphingomonas* sp., and *Bacillus* sp.

Table 3. Effect of 50, 100, 500 and 1000 mg/kg Pb and Zn metals on the survival of bacteria on 48 hours incubation

Sampling place	Total number of bacteria x10^7/m^3	Pb 50 x10^7/m^3	Pb 100 x10^7/m^3	Pb 500 x10^7/m^3	Pb 1000 x10^7/m^3	Zn 50 x10^7/m^3	Zn 100 x10^7/m^3	Zn 500 x10^7/m^3	Zn 1000 x10^7/m^3
Tisza	247	70	50	0	0	40	0.66	0	0
White Tisza	247	70	50	0	0	40	0.66	0	0
Black Tisza	247	70	50	0	0	40	0.66	0	0
Milota	247	198	187	3	0.3	51	30.4	3.52	2.5
Vásárosnamény	350	115	11.5	0.67	0.15	23	20.2	0.5	0.4
Dombrád	881	60	51	26	27	210	198	76	50
Szamos (Csenger)	710	120	70	40	6.5	213	88	92	20

Table 4. Effect of 50, 100, 500 and 1000 mg/kg Cu and Cd metals on the survival of bacteria on 48 hours incubation

Sampling place	Total number of bacteria x10^7/m^3	Cu 50 x10^7/m^3	Cu 100 x10^7/m^3	Cu 500 x10^7/m^3	Cu 1000 x10^7/m^3	Cd 50 x10^7/m^3	Cd 100 x10^7/m^3	Cd 500 x10^7/m^3	Cd 1000 x10^7/m^3
Tisza	247	0.56	0.33	0.033	0	0.44	0.033	0.0033	0
White Tisza	247	0.56	0.33	0.033	0	0.44	0.033	0.0033	0
Black Tisza	247	0.56	0.33	0.033	0	0.44	0.033	0.0033	0
Milota	247	77.5	4.5	3.74	0.1	40.2	7.2	0	0
Vásárosnamény	350	11.5	1.65	1.5	0.5	3	1.5	0	0
Dombrád	881	45	23	23	0	7.7	7	1	0
Szamos (Csenger)	710	240	65	65	3.5	2	2.5	2	0

Our results of microbial communities compounds shows the table 5. The isolated saprophytic bacteria and yeasts in the rivers (Tisza and Szamos) we found more than 38 different strains which were over 10 percentages.

Table 5. The isolated bacteria and yeasts species on the sampling points

Aeromonas hydrophila /caviae
Aeromonas salmonella salmonicida
Agrobacter radiobacter
Branhamella catarrhalis
Candida glabrata
Candida humicola
Candida inconspicua
Candida lambica
Candida magnoliae
Candida ssp.
Cryprococcus ssp.
Cryptococcus laurentii
Cryptococcus ssp.
Cryptococcus terreus
Cryseomonas luteola
Enterobacter agglomerans
Flavobacterium indologenes
Flavobacterium meningosepticum
Klebsiella apis/apiculata
Neisseria ssp.
Pasteurella ssp.
Pseudomonas chlororaphis
Pseudomonas ssp.
Pseudomonas chlororaphis
Pseudomonas stutzei
Pseudomonas vesicularis
Psudomonas pseudomallei
Rhodotorula minuta
Saccharomyces cerevisiae
Sphingomonas paucimobilis
Trichosporon capitatum
Trichosporon cutaneum
Trichosporon pullulans
Trichosporon ssp.
Vibrio metschnikovii
Weeksella virosa ~Flaerobacter buevis
Xanthomonas malthophilia
Sphingomonas paucimobilis

Our conclusion the survival of high (1000 mg/kg) metals concentrations shows the table 6. Our results partly correspond with Jackson et. al. (2009) that he found that potentially metal-tolerant organisms in water are *Pseudomonas* sp., *Sphingomonas* sp., and *Bacillus* sp. We found that carried on the 1000 mg/kg metals 12 bacterial and yeasts genera: *Aeromonas* ssp, *Agrobacter* ssp *Candida* ssp, *Cryptococcus* ssp, *Cryreomonas* ssp, *Flavobacterium* ssp, *Neisseria* ssp. *Pasteurella* ssp. *Pseudomonas* ssp. *Rhodotorula* ssp, *Trichosporon* ssp, *Vibrio* ssp. and *Sphingomonas* ssp.

Table 6. The metal effects survived bacteria and yeasts species ont he sampling pionts

Aeromonas salmonella salmonicida
Agrobacter radiobacter
Candida humicola
Candida inconspicua
Candida lambica
Cryptococcus laurentii
Cryreomonas luteola
Flavobacterium indologenes
Flavobacterium meningosepticum
Neisseria ssp.
Pasteurella ssp.
Pseudomonas chlororaphis
Pseudomonas vesicularis
Rhodotorula minuta
Trichosporon cutaneum
Trichosporon pullulans
Vibrio metschnikovii
Sphingomonas paucimobilis

CONCLUSIONS

A variety of human pathogens can be transmitted orally by water (WHO data) and in the developed world water quality regulations require that potable water does not contain any microbial pathogens (Percival and Walker, 1999). Water is vital for human life, for commercial and industrial purposes and is used for leisure activities in the daily lives of the entire world population. Water quality is assessed using a number of factors, e.g. microbial load (Lehtola et al., 2004) and nutrient content which affects microbial survival. The risk assessment of the heterotrophic bacteria revealed that the majority of the strains for the natural environmental status the rivers which many times proved as sources of drinking water. The rivers which are contaminated by human sources bacteria and as root of drinking water many times contaminated antibiotic resistant micro-organisms. This microflora poses significant health hazards to the consumers (Jeene et al., 2006).

Our results proved that rivers which are polluted by human sources waste water continuously contain health hazard for the people. According to our measurement the natural rivers (Tisza and Szamos) didn't content high concentration of metals (Cu, Cd, Pb, Zn). This metal content regularly matched to the Hungarian standard. In 2000 years, large amount of mud polluted with heavy metals and cyanides got into the River Tisza affected for the microbiological life. Our results show that almost 50 percentages of microbial genera were killed by the high concentration of heavy metals. The number of micro-organisms decreased.

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BIOECONOMY. WHAT IS BIOECONOMY? HOW WILL BIOECONOMY DEVELOP THE NEXT TWO DECADES?

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Abstract. This article speaks about bioeconomy, what does this mean and its effect upon other sciences. We will also have a quick look upon biotechnology and find the boundary between bieconomics and biotechnology. How did this develop in OECD (Organization for economic co-operation and development) and non-OECD countries? How will agriculture, health and industry fields develop for the next two decades? An important factor in bioeconomy development will be the increase of population, countries policy and their state of development.
Bioeconomy will develop continually in the next years and will be a set of new opportunities and challenges.

Key words: bioeconomy, agriculture, OECD, biotechnology, business, emarge, health, industry, 2030.

INTRODUCTION TO BIOECONOMY

Bioeconomy is a progressive branch of social science that seeks to integrate the disciplines of economics and biology for the sole purpose of creating theories that do a better job explaining economic events using a biological basis and vice versa.

The proponents of bioeconomy believe that the same patterns that can be seen in biological evolution can be applied to stock market behavior, as many of the same "causal interactions" and "survival elements" can be found there as well as in nature.

In nature, we see groups of different organisms working together to best utilize the resources needed to sustain life, while still promoting as "survival of the fittest" framework. Like behavioral finance and other applied economic schools, bioeconomy is another example of economic theory branching out of classical boundaries and attempting to better explain the complex economies of today.

It studies the dynamics of living resources using economic models. Bioeconomy is an attempt to apply the methods of environmental economics and ecological economics to empirical biology.

Bioeconomy is the science determining the socioeconomics activity threshold for which a biological system can be effectively and efficiently used without destroying the conditions for its regeneration and therefore its sustainability.

BIOTECHNOLOGY AND BIOECONOMY

Over the past two decades, biotechnology has provided a motor for environmentally sustainable production and for the development of a diverse range of innovative products. The continued commercial application of biotechnology could lead to the development of a bioeconomy, where a substantial share of economic output is partly dependent on the development and use of biological materials. The potential economic and environmental benefits of biotechnology have created a growing strategic interest in the bioeconomy in both OECD (Organisation for economic co-operation and development) and non-OECD countries. But for the bioeconomy to succeed, considerable uncertainties and global challenges will need to be addressed.

Innovative policy frameworks, strategic thinking by both governments and firms, and citizen support will be required to meet these challenges.

Advances in biotechnology-related fields such as genomics, genetic engineering, chemical engineering and cell technology are transforming the industrial and environmental process and management landscapes. Microorganisms, enzymes or their products are replacing processes that depended heavily on chemicals, many of which are implicated in environmental damage. However, much discussion of biotechnology currently focuses on agricultural applications (and some extent biomedical uses).

The role biotechnology could play in addressing what are considered the most serious challenges to world economies and societies over the next decades. These challenges include *agriculture, healthcare, industry* and other resources and services to a world that will see its population increase by a third in the face of mounting environmental stresses over the next 20 years.

1. In *agriculture*, encourage the application of biotechnology to improve plant and animal varieties through improving access to technologies for use in a wider range of plants, expanding the number of firms and research institutes that can use biotechnology (particularly in developing countries), and fostering public dialogue.
2. In *health (bioinformatics)*, develop regulatory, research, and health record systems which can link prescribing histories, genetic and other

information, to support long-term follow-up research into health outcomes.

3. In *industry*, increase support for the adoption and use of internationally accepted standards for life cycle analysis, along with other incentives to reward environmentally sustainable technologies (*e.g.* boosting research into high energy density bio fuels).

The bioeconomy can have a major impact in many of these areas to ensure long term economic and environmental sustainability.

Since its emergence, modern biotechnology has been associated with debates concerning benefits and risks. The ability to transform life itself in order to generate new products and services has been classified as a revolutionary technology, with the same societal impacts as the information and communications revolution. With these high explications have also come fears and concerns, which have captured public and policy attention worldwide. Concealed in the narrower debates about the impacts of biotechnology on human health and the environment are wider concerns about socio-economic considerations, which can be translated into market dislocations.

Indeed, early concerns about agricultural biotechnology focused on the possible impacts of genetic engineering or shifting the locus of production of raw materials.

The adoption pace witnessed in the fields of biotechnology is consistent with previous trends in other generic technologies. The rate of diffusion will be fastest where biotechnology creates new products that do not complete with existing applications. In the field of health care, for example, new diagnostic methods for a wide range of biological and non-biological expressions could involve such products. The pace will be slow and possibly punctuated by controversy where biotechnology seeks to displace existing processes and products or enhances the competitiveness of certain products.

TECHNOLOGICAL INNOVATION

The last century saw the replacement of plant-derived products with petroleum derivatives.

These remarkable transformations helped humanity to overcome some of the natural limitations of relying on natural processes. The change was largely a result of advances in chemistry and allied fields. This century promises to open new avenues for increasing the use of renewable resources in the global economy. These trends will open up new opportunities for the participation of OECD and non OECD countries in the new bioeconomy. But, as in previous technological revolutions, the promise and reality are different. In the case of agricultural biotechnology, for example, only a handful of developing countries have so far managed to become players in the global economy. The rest have little hope of playing significant roles in the near future. As in other technological fields, participation in the new bioeconomy will be uneven and limited to those countries that make the necessary investments in technological development.

So far, much of the research on policy aspects of biotechnology has focused on agricultural and pharmaceutical biotechnology (*health*). The field of industrial and environmental biotechnology remains understudied. Industrial biotechnology covers two distinct areas. The first area is the use of renewable raw materials (biomass) to replace raw material derived from fossil fuels. The second is the use of biological systems such as cells or enzymes (used as reagents or catalysts) to replace conventional, non-biological methods.

Industrial applications of biotechnology are emerging as a spin-off from developments in other fields such as the pharmaceutical sector. This is largely because industrial biotechnology has not received the same level of public policy attention as has biotechnology in other sectors. There are other structural factors influencing the diffusion of industrial biotechnology. These include the dominance of physical and chemical technology as a source of concepts for the design of industrial plants, which limits the scope for introducing biological processes.

BIOECONOMY IN OECD AND NON-OECD COUNTRIES

The biological sciences are adding value to a host of products and services, producing what some have labeled the “bioeconomy”. The bioeconomy could make major socioeconomic contributions in OECD (Organization for economic co-operation and development) and non-OECD countries. These benefits are expected to improve health outcomes, boost the productivity of agriculture and industrial processes, and enhance environmental sustainability. The bioeconomy’s success is not, however, guaranteed: harnessing its potential will require coordinated policy action by governments to reap the benefits of the biotechnology revolution.

The Bioeconomy to 2030: Designing a Policy Agenda begins with an evidence-based technology approach, focusing on biotechnology applications in primary production, health, and industry. It describes the current status of biotechnologies and, using quantitative analyses of data on development pipelines and R&D expenditures from private and public databases, it estimates biotechnological developments to 2015. Moving to a broader institutional view, it also looks at the roles of R&D funding, human resources, intellectual property, and regulation in the bioeconomy, as well as at possible developments that could influence emerging business models.

Both OECD and developing countries face a range of environmental, social, and economic challenges over the next two decades. Rising incomes, particularly in developing countries, will increase demand for healthcare and for agricultural, forestry, and fishing products. At the same time, many of the world's ecosystems that support human societies are overexploited and unsustainable. Climate change could exacerbate these environmental problems by adversely affecting water supplies and increasing the frequency of drought.

Biotechnology offers technological solutions for many of the health and resource-based problems facing the world. The application of biotechnology to primary production, health and industry could result in an emerging "bioeconomy" where biotechnology contributes to a significant share of economic output. The bioeconomy in 2030 is likely to involve three elements: advanced knowledge of genes and complex cell processes, renewable biomass, and the integration of biotechnology applications across sectors.

WHAT EXTERNAL FACTORS WILL EMARGE THE BIOECONOMY TO 2030?

Several factors will drive the emerging bioeconomy by creating opportunities for investment. A major factor is increasing population and per capita income, particularly in developing countries. The global population is expected to reach 8.3 billion in 2030, with 97% of the growth occurring in developing countries. GDP is expected to grow by 4.6% per year in developing countries and by 2.3% in OECD countries. These trends in population and income, combined with rapid increases in educational achievement in China and India, indicate not only that the bioeconomy will be global but that the main markets for biotechnology in primary production (agriculture, forestry and fishing) and industry could be in developing countries. Increases in energy demand, especially if combined with measures to reduce greenhouse gases, could create large markets for biofuels.

An expected increase in elderly populations, both in China and in OECD countries, will increase the need for therapies to treat chronic and neurodegenerative diseases, some of which will be based on biotechnology. Many countries and healthcare providers will try to reverse rapidly increasing healthcare costs. Biotechnology provides possible solutions to reduce the cost of pharmaceutical and manufacturing. Alternatively, biotechnology could improve the cost-effectiveness of health therapy, so that expensive treatments provide commensurate and significant improvements to health and the quality of life.

BIOECONOMY TODAY

Biotechnology today is used in primary production, health and industry. Platform technologies such as genetic modification, DNA sequencing, bioinformatics and metabolic pathway engineering have commercial uses in several application fields. The main current uses of biotechnology in primary production are for plant and animal breeding and diagnostics, with a few applications in veterinary medicine. Human health applications include therapeutics, diagnostics, pharmaco-genetics to improve prescribing practices, functional foods and nutraceuticals, and some medical devices.

Industrial applications include the use of biotechnological processes to produce chemicals, plastics, and enzymes, environmental applications such as bioremediation and biosensors, methods to reduce the environmental effects or costs of resource extraction, and the production of bio fuels. Several applications, such as biopharmaceuticals, in vitro diagnostics, some types of genetically modified crops, and enzymes are comparatively "mature" technologies. Many other applications have limited commercial viability without government support (e.g. bio fuels and biomining) or are still in the experimental stage, such as regenerative medicine and health therapies based on RNA interference.

BYOECONOMY OF 2030. CHALLENGES AND OPPORTUNITIES.

Bioeconomy builds on the types of products that are likely to reach the market in the next future. Within the OECD region, biotechnology could contribute to 2.7% in 2030, with the largest economic contribution of biotechnology in industry and in primary production. The economic contribution of biotechnology could be even greater in developing countries, because of the importance of these sectors to their economies.

The scenarios assume an increasingly multi-polar world, with no single country or region dominating world affairs. They include plausible events that could influence the emerging bioeconomy. The results highlight the importance of good governance, including international cooperation, and technological competitiveness in influencing the future. Complex scientific challenges and poorly designed regulations could reduce the ability of industrial biotechnologies to compete with other alternatives.

Social, economic and technological factors will create new business opportunities for biotechnology, requiring new types of business models.

The main business models to date have been the small, dedicated biotechnology firm that specializes in research and sells knowledge to large firms, and the large integrated firm that performs pharmaceutical and manufactures and distributes products.

Agriculture	Health	Industry
Widespread use of marker assisted selection (MAS) in plant, livestock, fish and shellfish breeding.	Many new pharmaceuticals and vaccines, based in part on biotechnological knowledge, receiving marketing approval each year.	Improved enzymes for a growing range of applications in the chemical sector.
Genetically modified (GM) varieties of major crops and trees with improved starch, oil, and lignin content to improve industrial processing and conversion yields.	Greater use of pharmacogenetics in clinical trials and in prescribing practice, with a fall in the percentage of patients eligible for treatment with a given therapeutic.	Improved micro-organisms that can produce an increasing number of chemical products in one step, some of which build on genes identified through bioprospecting.
GM plants and animals for producing pharmaceuticals and other valuable compounds.	Improved safety and efficacy of therapeutic treatments due to linking pharmacogenetic data, prescribing data, and long-term health outcomes.	Biosensors for real-time monitoring of environmental pollutants and biometrics for identifying people.
Improved varieties of major food and feed crops with higher yield, pest resistance and stress tolerance developed through GM, MAS, intragenics or cisgenesis.	Extensive screening for multiple genetic risk factors for common diseases such as arthritis where genetics is a contributing cause.	High energy-density bio fuels produced from sugar cane and cellulosic sources of biomass.
More diagnostics for genetic traits and diseases of livestock, fish and shellfish.	Improved drug delivery systems from convergence between biotechnology and nanotechnology.	Greater market share for biomaterials such as bioplastics, especially in niche areas where they provide some advantage.
Cloning of high-value animal breeding stock.	New nutraceuticals, some of which will be produced by GM micro-organisms and others from plant or marine extracts.	
Major staple crops of developing countries enhanced with vitamins or trace nutrients, using GM technology.	Low-cost genetic testing of risk factors for chronic diseases such as arthritis, Type II diabetes, heart disease, and some cancers.	
	Regenerative medicine providing better management of diabetes and replacement or repair of some types of damaged tissue.	

Source: The Bioeconomy to 2030 “DESIGNING A POLICY AGENDA”
Main Findings and Policy Conclusions

POLICY OPTIONS FOR THE BIOECONOMY: THE WAY AHEAD

The social and economic benefits of the bioeconomy will depend on good policy decisions. The required mix of policies is linked to the potential economic impacts of biotechnological innovations on the wider economy. Each type of innovation can have incremental, disruptive or radical effects. In many cases incremental innovations fit well within existing economic and regulatory structures. Disruptive and radical innovations can lead to the demise of firms and industrial structures, creating greater policy challenges, but they can also result in large improvements in productivity. This chapter identifies policy options to address challenges in primary production, health and industrial biotechnology. It also looks at cross-cutting issues for intellectual property and for knowledge spillovers and integration, global challenges, and the need to develop policies over both the short and long term.

Primary production provides a diverse range of policy challenges. Examples include the need to simplify regulation, encourage the use of biotechnology to improve the nutritional content of staple crops in developing countries, ensure unhindered trade in agricultural commodities, and manage a decline in the economic viability of cool-climate forestry resources for low value commodities such as pulp and paper. The main challenges for health applications are to better align private incentives for developing health therapies with public health goals and to manage a transition to regenerative medicine and predictive and preventive medicine, both of which could disrupt current healthcare systems. Industrial biotechnology faces multiple futures due to competitive alternatives from both outside and within biotechnology. Policy needs to flexibly adapt to different outcomes and prevent "lock-in" to inferior technological solutions.

CONCLUSIONS: ON THE ROAD TO THE BIOECONOMY

Obtaining the full benefits of the bioeconomy will require purposive goal-oriented policy. This will require leadership, primarily by governments but also by leading firms, to establish goals for the application of biotechnology to primary production, industry and health; to put in place the structural conditions required to achieve success such as obtaining regional and international agreements; and to develop mechanisms to ensure that policy can flexibly adapt to new opportunities. There are nine main challenges, summarized in this chapter.

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