**LECTURE No. 3: ECO-DESIGN AND SUSTAINABLE MEDICAL TECHNOLOGIES. LEGAL AND ETHICAL ASPECTS OF THE GREEN TRANSITION IN MEDICINE**

**Duration:** 2 academic hours (90 minutes)

**INTRODUCTION**

**Dear students!**

In the previous lectures, we discussed how climate change affects public health, what environmental problems the activities of healthcare organizations create, and how waste, energy, and water can be managed. Today we rise to the next level: from operational management we move to **strategic design**.

Imagine that you are not just a physician treating a patient today, but a person who influences what medicine will look like in 10, 20, 50 years. What medical products will be used? How will they be produced? What will happen to them after use? And how can we combine two seemingly opposite values: **patient safety** and **environmental sustainability**?

Today we will examine:

1. What is eco-design and how is it applied in medicine?
2. How to choose eco-friendly medical products (green procurement criteria)?
3. Disposable and reusable — how to find a balance?
4. What is the circular economy in healthcare?
5. What legal and ethical dilemmas arise during the "green" transition?

**1. ECO-DESIGN IN MEDICINE: FROM CONCEPT TO PRACTICE**

**What is eco-design?**

**Eco-design (ecological design)** is an approach to product design that takes into account the impact on the environment at all stages of the life cycle: from raw material extraction to disposal. The goal of eco-design is to minimize the negative impact while preserving the functionality, safety, and quality of the product.

In the context of medicine, eco-design means creating medical products, medications, equipment, and packaging with consideration of their environmental footprint.

**Principles of eco-design in medicine**

| Principle | What it means | Example in medicine |
|---|---|---|
| **Minimization of materials** | Use less raw material for production | Reducing packaging thickness while maintaining sterility |
| **Choice of eco-friendly materials** | Use renewable, recyclable, or biodegradable materials | Transition from plastic to paper for instrument packaging |
| **Energy efficiency of production** | Reduce energy consumption at all stages | Use of solar energy at medical product manufacturing plants |

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| **Increasing service life** | Design products that last longer | Reusable surgical instruments made of titanium |
| **Repairability and upgradability** | Products should be repaired rather than replaced | Modular equipment (CT, MRI) where individual units can be replaced |
| **Ease of disassembly for recycling** | The product should easily separate into components for recycling | Syringe design where metal and plastic easily separate |
| **Reduction of toxicity** | Elimination of hazardous substances | Replacement of mercury thermometers and tonometers with safe alternatives |

**Why is eco-design important in medicine?**

Medical products are traditionally designed with priority on **safety and efficiency**, and this is absolutely correct. However, environmental aspects have long remained in the background. The situation is changing for several reasons:

**Reason 1: Scale of the problem**

The healthcare sector generates about 4-5% of global greenhouse gas emissions. Production and disposal of medical products account for a significant part of this footprint.

**A figure for reflection:**

Surgical procedures alone generate millions of tons of waste annually. For example, one hip replacement surgery creates from 8 to 15 kg of medical waste.

**Reason 2: Resource constraints**

Many materials used in medicine (rare earth metals for electronics, platinum for some types of equipment, polymers from oil) are limited resources. Eco-design contributes to their more rational use.

**Reason 3: Regulatory pressure**

More and more countries are introducing requirements for the environmental friendliness of medical products. In the European Union, the Eco-design Directive is in force, which also applies to medical equipment.

**Reason 4: Economic benefit**

Eco-design often leads to reduced production and disposal costs. For example, reducing packaging lowers transport and storage costs.

**Examples of eco-design in medicine**

**Example 1: Eco-friendly packaging for surgical kits**

Traditionally, surgical kits are packaged in several layers of plastic and paper. A company producing surgical instruments developed packaging that is 30% lighter and 25% smaller in volume, while maintaining sterility. This allowed reducing transport emissions by 20% and reducing the amount of packaging waste.

**Example 2: Reusable drug delivery system**

Instead of disposable syringes for administering certain medications, a reusable injection system was developed. The only disposable element is the needle and a small cartridge with the medication. The remaining components are sterilized and used repeatedly. According to estimates, this reduces waste by 70% compared to a fully disposable system.

**Example 3: Biodegradable implants**

Traditional implants (e.g., for osteosynthesis) require repeat surgery for removal after bone healing. Biodegradable implants made of polymers based on lactic acid gradually dissolve in the body, not requiring repeat intervention. This not only reduces the risk of surgical complications but also eliminates the need for repeat surgery, with all the associated emissions and waste.

**Mechanism of action:**

Polymers based on polylactide (PLA) and polyglycolide (PGA) are hydrolyzed in the body, releasing lactic and glycolic acids, which are naturally metabolized. The degradation rate can be controlled by changing the molecular weight and the ratio of monomers.

## 2. GREEN PROCUREMENT IN HEALTHCARE

**What is green procurement?**

**Green Public Procurement (GPP)** is the process of selecting goods, services, and works with lower environmental impact throughout their life cycle. In healthcare, this means that when procuring medical products, medications, equipment, and services, not only price and technical characteristics are considered, but also environmental criteria.

**Why is green procurement important?**

1. **Scale of procurement in healthcare**

Hospitals purchase a huge number of goods: from medications and syringes to complex diagnostic equipment and furniture. These purchases form a significant part of the environmental footprint of healthcare. According to estimates, procurement of goods and services (Scope 3) accounts for up to 70% of the carbon footprint of healthcare organizations.

**A figure for reflection:**

An average 400-bed hospital purchases more than 50,000 different items per year.

2. **The "leverage" effect**

Healthcare is a major buyer. Changing requirements for suppliers on the part of hospitals forces manufacturers to reconsider their production processes and introduce more environmentally friendly solutions.

3. **Cost savings**

Although "green" products may have a higher initial price, their total cost of ownership (TCO) is often lower due to reduced costs for energy, water, disposal, and a longer service life.

**Green procurement criteria in healthcare**

**Criterion 1: Material composition**

- Preference for materials with a smaller environmental footprint (recycled plastic instead of virgin, biodegradable materials)
- Exclusion of hazardous substances (phthalates, bisphenol A, mercury, lead, cadmium)
- Labeling on recycled content

**Criterion 2: Packaging**

- Minimal packaging while maintaining sterility
- Use of recyclable materials
- Elimination of excessive use of plastic
- Possibility of returning packaging for reuse

**Criterion 3: Energy efficiency during use**

- Energy efficiency labeling for equipment
- Presence of energy-saving modes
- Use of renewable energy sources in production

**Criterion 4: Durability and repairability**

- Expected service life
- Availability of spare parts
- Possibility of repair instead of replacement
- Modular construction

**Criterion 5: Management at the decommissioning stage**

- Recyclability
- Return and disposal programs from the manufacturer
- Absence of hazardous materials that complicate disposal

**Criterion 6: Environmental responsibility of the manufacturer**

- Presence of an environmental policy
- Certification (ISO 14001, EMAS)
- Social responsibility

**How does green procurement work in practice?**

**Stages of implementing green procurement:**

1. **Development of environmental criteria** — determination of which criteria will be used for each category of goods.
2. **Inclusion of criteria in tender documentation** — environmental requirements become mandatory conditions for participation in procurement.

3. **Training of procurement commissions** — commission members must be able to assess the environmental aspects of proposals.
4. **Comparison of proposals by life cycle criteria** — assessment not only of price but also of total cost of ownership taking into account environmental factors.
5. **Monitoring of contract execution** — verification that the supplier complies with environmental requirements.

**Practical example from practice:**

A hospital in Scandinavia, when procuring intravenous infusion systems, included the following environmental requirements in the tender:

- Packaging must be 100% recyclable
- Plastic components must contain at least 30% recycled material
- The manufacturer must have a program for returning used systems
- The energy consumption of the infusion pump must not exceed 15 W

As a result, the winner was a supplier who offered a system with the lowest total cost of ownership and the smallest environmental footprint, despite the fact that the price of the device itself was higher than that of competitors.

**Barriers to green procurement and ways to overcome them**

| Barrier | Way to overcome |
|---|---|
| **Higher initial price** | Calculation of total cost of ownership taking into account costs for energy, water, disposal |
| **Lack of information** | Creation of databases of environmentally preferable products |
| **Personnel resistance** | Training and educational work |
| **Lack of legal framework** | Development of national and regional regulatory documents |
| **Limited choice** | Stimulating manufacturers through consolidation of procurement |

## 3. DISPOSABLE AND REUSABLE PRODUCTS: FINDING A BALANCE

**The classic dilemma**

One of the most difficult questions in sustainable healthcare: **what is better — disposable or reusable products?**

| Aspect | Disposable | Reusable |
|---|---|---|
| **Infection risk** | Minimal (factory sterilization) | Risk during sterilization (personnel error, equipment malfunction) |
| **Convenience** | High (ready to use) | Requires logistics of collection, washing, sterilization |

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| **Environmental footprint** | High (production, disposal) | Depends on the region (energy for sterilization, water for washing) |
| **Economic efficiency** | Often higher per 1 use | Lower per 1 use, but may be more cost-effective with a large number of uses |
| **Reliability** | Guaranteed sterility | Depends on the quality of sterilization |

**When are disposable products more environmentally friendly than reusable ones?**

It sounds paradoxical, but in some cases disposable products can be more environmentally friendly than reusable ones. This happens when:

**Situation 1: Sterilization requires a huge amount of energy and water**

In regions where electricity is produced from coal, and water is a scarce resource, reusable products may have a larger carbon footprint than disposable ones.

**Example from practice:**

A study compared disposable and reusable sensors for monitoring neuromuscular transmission in the operating room. Both performed the same clinical function with the same accuracy and safety. In terms of $CO_2$ emissions per single application, **the disposable sensor turned out to be the more sustainable choice**.

**Why?** Because sterilization of the reusable sensor required energy for autoclaving, water for rinsing, chemicals for disinfection, as well as logistics (transportation back and forth).

**Situation 2: High risk of infection**

For procedures with a high risk of infectious complications (e.g., when working with patients with particularly dangerous infections), disposable products may be preferable, as they are guaranteed sterile and their disposal does not require complex disinfection.

**Situation 3: Complex geometry of the product**

Some products have a complex shape (e.g., endoscopic instruments) and are difficult to clean and sterilize well. In such cases, disposable options may be safer.

**When are reusable products more environmentally friendly and cost-effective?**

**Situation 1: High turnover**

If a product is used many times a day (e.g., surgical instruments in a large operating room), the reusable option becomes economically and environmentally advantageous.

**Calculation:**

- Disposable scalpel: 100 som per piece
- Reusable scalpel: 1,000 som, withstands 100 sterilizations
- Cost of one sterilization: 5 som
- Cost of 100 uses of the reusable one: $1,000 + (100 \times 5) = 1,500$ som
- Cost of 100 disposable ones: $100 \times 100 = 10,000$ som
- Savings: 8,500 som. Plus a 99% reduction in waste.

**Situation 2: Low carbon footprint of electricity**

In regions with low-carbon electricity (hydroelectric power plants, nuclear stations, wind turbines), the energy costs of sterilization have less impact on the climate.

**Situation 3: High quality of sterilization**

In large hospitals with central sterilization departments and trained personnel, the quality of sterilization corresponds to factory levels.

**Practical recommendations for decision-making**

1. **Conduct a life cycle assessment (LCA) for each category of products** — without data it is impossible to make an informed decision.
2. **Take into account regional factors** — source of electricity, availability of water, cost of disposal.
3. **Create a "menu" of choice** — different options may be optimal for different clinical situations.
4. **Involve clinical personnel in the decision-making process** — it is physicians and nurses who know how the product is used in real practice.
5. **Gradually introduce changes** — start with categories where the balance is obvious.

## 4. CIRCULAR ECONOMY IN HEALTHCARE

**What is the circular economy?**

**The circular economy** is an economic system in which products and materials are kept in use for as long as possible, maximum value is extracted during use, and at the end of the service life materials are recovered and regenerated to create new products.

Unlike the **linear economy** ("take — make — dispose"), the circular economy strives for a closed cycle.

**Principles of the circular economy in healthcare**

| Principle | What it means | Example in medicine |
|---|---|---|
| **Preservation and extension of service life** | Repair, modernization of equipment instead of replacement | Modernization of a CT scanner instead of complete replacement |
| **Reuse** | Use of products multiple times | Textile surgical caps and masks |
| **Refurbishment** | Restoration of used products to a like-new condition | Refurbished endoscopes for training or use in resource-limited regions |
| **Recycling** | Conversion of waste into raw material for new products | Recycling of sterilized plastic from medical waste into construction materials |
| **Reduction of consumption (reduce)** | Use of less materials and energy | Eco-design of packaging |

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| **Replacement (replace)** | Replacement of hazardous and resource-intensive materials with alternatives | Transition to reusable drug delivery systems |

**Examples of the circular economy in medicine**

**Example 1: Recycling of sterilized medical waste (the "Naryn Model")**

In Kyrgyzstan, the medical waste management system includes a recycling stage. After autoclaving (steam sterilization under pressure), the plastic and metal parts of medical waste become safe and can be recycled into secondary raw materials.

**Technological process:**

1. Sorting of waste at the source
2. Loading into autoclavable containers
3. Sterilization in an autoclave at 134°C for 18 minutes
4. Crushing and shredding of sterilized plastic
5. Use of recycled plastic for the production of construction materials, landscape design elements, and other non-food products

**Example 2: Refurbishment of medical equipment**

In developed countries, equipment refurbishment is a fast-growing sector. Large manufacturers offer programs under which used equipment (MRI, CT, ultrasound machines) is restored to factory specifications and sold at a lower price.

**Advantages:**

- Reduction of electronic waste
- More affordable equipment for resource-limited countries
- Reduced carbon footprint compared to producing new equipment

**Example 3: Circular models in pharmaceuticals**

Pharmaceutical companies are beginning to introduce programs for returning used packaging, as well as developing dosing systems where the dispenser is reused and only the cartridge with the medication is replaceable.

**Barriers to the circular economy in healthcare**

| Barrier | Description |
|---|---|
| **Regulatory restrictions** | Medical products must comply with strict requirements, which often involve the use of new materials and disposable products |
| **Infection risk** | Recycling of medical waste requires strict sterility control |
| **Economic incentives** | It is often more profitable for manufacturers to sell new products than to restore old ones |

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| **Personnel resistance** | Refurbished products may be perceived as less reliable |
| **Lack of infrastructure** | In many regions there are no collection and recycling systems |

## 5. LEGAL ASPECTS OF THE GREEN TRANSITION IN MEDICINE

**International level**

1. **EU Eco-design Directive (2009/125/EC)**

Establishes eco-design requirements for energy-using products, including medical equipment. The Directive requires manufacturers to take into account environmental aspects at all stages of the life cycle.

2. **Stockholm Convention on Persistent Organic Pollutants (POPs)**

Restricts the production and use of persistent organic pollutants, including dioxins, which are formed during the incineration of medical waste. Kyrgyzstan is a party to the Convention.

3. **Basel Convention on the Control of Transboundary Movements of Hazardous Wastes**

Regulates the transboundary movement of hazardous wastes, including medical ones.

**National level: Kyrgyz Republic**

**1. Government Decree No. 719 of 2019**

"On approval of the Rules for the management of medical waste and mercury-containing products in healthcare organizations."

**Key provisions:**

- Requirements for collection, temporary storage, transportation, and disposal of medical waste have been established
- A waste classification system has been introduced (Classes A-E)
- Requirements for personnel training have been established
- Sanctions for violations have been introduced

**2. Law of the Kyrgyz Republic "On Environmental Protection"**

Establishes general requirements for environmental protection, including waste management and atmospheric air protection.

**3. Sanitary Norms and Rules (SanPiN)**

Contain hygienic requirements for the design, equipment, and maintenance of hospitals, maternity hospitals, and other medical and preventive institutions, including requirements for ventilation, water supply, and waste management.

**4. Labor Code of the Kyrgyz Republic**

Contains norms on labor protection of medical workers, including protection from biological and chemical factors.

**The gap between the legal framework and practice**

Despite the existence of legislation, its practical implementation faces problems:

1. **Lack of funding** — the introduction of waste management systems and energy-saving technologies requires investments
2. **Lack of training** — personnel do not always know the requirements of legislation
3. **Lack of control** — control over compliance with legislation is often insufficient
4. **Outdated infrastructure** — many hospitals were built decades ago and do not meet modern requirements

## 6. ETHICAL ASPECTS OF THE GREEN TRANSITION IN MEDICINE

**The ethical dilemma: patient safety and environmental sustainability**

This is the central ethical question in sustainable healthcare. How can we combine the fundamental principle of medical ethics "do no harm" (primum non nocere) with the duty not to harm the planet?

**Formulation of the dilemma:**

On the one hand, the physician is obliged to do everything possible for the safety of a specific patient today. This may mean using disposable products, more diagnostic procedures, more aggressive treatment.

On the other hand, the physician as a member of society is obliged to care for the health of future generations. This may mean more restrained use of resources, choosing environmentally safer alternatives.

**How to resolve the dilemma?**

Experts propose the following approaches:

1. **Patient safety is always priority No. 1**

Environmental considerations must never compromise patient safety. If there are doubts about the safety of a reusable product, the disposable one should be chosen.

2. **Environmental sustainability is part of safety**

Deterioration of the state of the environment is a threat to public health. Therefore, care for the environment is also care for health, only at the population level.

3. **Search for solutions**

It is important to look for solutions that simultaneously improve patient safety and environmental sustainability.

**Example:**

Switching from inhalation anesthesia (sevoflurane, desflurane) to intravenous (propofol) may be more environmentally friendly, as inhalation anesthetics are powerful greenhouse gases. In some cases, intravenous anesthesia also provides more stable hemodynamics and less postoperative stress.

**Principles of ethical decision-making in "green" medicine**

**1. Principle of informed consent**

Patients have the right to know about the environmental aspects of treatment. The physician must explain why a particular approach is chosen.

**Example:**

"We offer you a reusable surgical gown. It is sterile and safe. Compared to a disposable one, it has a significantly smaller environmental footprint, as it does not require the production of new materials. However, if you insist on a disposable one, we can use it."

**2. Principle of justice**

The environmental burden should not be distributed unevenly among population groups. Vulnerable groups should not suffer from the environmental consequences of medical activity to a greater extent than others.

**3. Principle of professional responsibility**

Physicians bear professional responsibility not only for the health of specific patients but also for the health of the population as a whole. This means the duty to participate in "green" initiatives and promote environmentally responsible behavior among colleagues and patients.

**4. Principle of precaution**

When there is uncertainty regarding the environmental consequences of a particular decision, the option with less potential harm to the environment should be chosen, if this does not contradict patient safety.

**Practical examples of ethical dilemmas and their resolution**

**Dilemma 1: Disposable instruments in dentistry**

**Situation:** A dental clinic uses disposable mirrors and probes. From the point of view of infection control, this is safe. But the amount of waste is enormous.

**Solution:**

After an LCA assessment, it was decided to use reusable stainless steel instruments that are sterilized in an autoclave. For patients with immunodeficiency or infectious diseases, a set of disposable instruments is reserved.

**Dilemma 2: Medication packaging**

**Situation:** Many medications are supplied in individual packaging (blisters), which is not recyclable.

**Solution:** The hospital begins to require suppliers to provide bulk packaging (bottles) for frequently used medications, where it is safe. The remaining packaging is sorted for recycling where possible.

**Dilemma 3: Laboratory tests**

**Situation:** Each test uses disposable tubes, tips, and reagents. Laboratory waste constitutes a significant part of medical waste.

**Solution:**

Introduction of the minimum necessary volume of blood for tests, use of microtubes, optimization of protocols to reduce the number of repeat tests.

## 7. BIODEGRADABLE MATERIALS IN MEDICINE

### What are biodegradable materials?

**Biodegradable materials** are materials that, under the action of microorganisms (bacteria, fungi), decompose into natural components (water, carbon dioxide, biomass) within a reasonable period of time.

In medicine, biodegradable materials are used in two main categories:

### 1. Implants and temporary medical devices

These materials are intended for temporary presence in the body and subsequent biodegradation.

**Examples:**

- Suture materials (polyglycolide, polylactide)
- Biodegradable implants for osteosynthesis
- Biodegradable stents
- Biodegradable drug delivery systems

### 2. Packaging and disposable products

These materials decompose after disposal, reducing the burden on landfills.

**Examples:**

- Packaging from biodegradable polymers (PLA, PHB)
- Biodegradable cups and plates for patient nutrition
- Biodegradable bags for collecting medical waste

### Advantages and limitations of biodegradable materials

| Advantages | Limitations |
|---|---|
| Reduction of waste volume in landfills | Higher cost compared to traditional plastics |
| Reduction of emissions during disposal | Often require special conditions for decomposition |
| Possibility of use for implants (no second surgery needed) | May have lower mechanical characteristics |
| Less dependence on non-renewable resources | May release toxic substances during decomposition |

### Examples from practice

**Example 1: Biodegradable suture materials**

Modern surgical threads made of polylactide (PGA, PLGA) gradually hydrolyze in tissues, not requiring removal of sutures. They are completely safe, do not cause chronic inflammation, and dissolve within 2-6 weeks depending on composition.

**Example 2: Biodegradable implants for osteosynthesis**

Implants made of polylactic acid (PLA) are used for fracture fixation. They provide stability for 6-12 months, and then gradually dissolve. This eliminates the need for repeat surgery to remove the implant.

**Example 3: Biodegradable drug delivery systems**

Microparticles made of polymers (PLGA, PLA) are used for controlled release of medications. They gradually release the active substance over weeks or months, and then decompose into safe components.

**Biodegradable materials in the context of the circular economy**

It is important to understand that biodegradable materials are not a panacea. Their use should be part of an overall waste management strategy:

- **Priority:** reduction of use → reuse → recycling → composting (biodegradation)
- Biodegradable materials make sense where recycling is impossible or economically unfeasible
- Decomposition of biodegradable materials often requires industrial composting facilities, which are not available everywhere

## CONCLUSION

**Key conclusions of the lecture**

1. **Eco-design is the basis of the "green" transition.** Medical products must be designed with consideration of all stages of the life cycle.
2. **Green procurement is a powerful lever of influence.** Hospitals' requirements for the environmental friendliness of products stimulate manufacturers to introduce more sustainable solutions.
3. **There is no universal answer to the question "disposable vs reusable."** The decision must be made on the basis of LCA taking into account regional characteristics.
4. **The circular economy changes the approach to waste.** Waste is considered not as a problem but as a resource.
5. **The legal framework in Kyrgyzstan exists but requires strengthening of control and funding.**
6. **Ethical dilemmas require balanced decisions.** Patient safety is a priority, but the physician is obliged to minimize environmental damage where it is safe.
7. **Biodegradable materials are a promising direction,** but not a universal solution. Their use should be part of an overall sustainability strategy.

## QUESTIONS FOR REFLECTION

1. **Why have environmental aspects long been ignored in product design in medicine?**

2. **How can green procurement improve not only the environmental situation but also the quality of medical care?**
3. **In which clinical situations would you choose a disposable product, even if LCA showed the advantages of a reusable one?**
4. **Do you think the patient's right to informed choice should extend to the environmental aspects of treatment?**
5. **Which barriers to the introduction of the circular economy in healthcare in Kyrgyzstan are the most critical?**

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