KAUNAS UNIVERSITY OF TECHNOLOGY
FACULTY OF MATHEMATICS AND NATURAL SCIENCES
DEPARTMENT OF PHYSICS

Rūta Partauskaitė

Investigation of photon induced degradation of contact lenses

Final project of master degrees

Supervisor

Doc. Judita Puišo

KAUNAS, 2017

KAUNAS UNIVERSITY OF TECHNOLOGY
FACULTY OF MATHEMATICS AND NATURAL SCIENCES

INVESTIGATION OF PHOTON INDUCED DEGRADATION OF CONTACT LENSES

Final project of master degrees
Medical physics 621B92002

Supervisor

(parašas) Doc. Judita Puišo

(data)

Reviewer

(parašas) Dr. Karolis Gedvilas

(data)

Project made by

(parašas) Rūta Partauskaitė

(data)

KAUNAS, 2017

KAUNO TECHNOLOGIJOS UNIVERSITETAS

Matematikos ir gamtos mokslų fakultetas

(Fakultetas)

Rūta Partauskaitė

(Studento vardas, pavardė)

Medicinos fizika, 621B92002

(Studijų programos pavadinimas, kodas)

„Fotoninių srautų poveikio kontaktinių lęšių degredacijai tyrimas"

AKADEMINIO SĄŽININGUMO DEKLARACIJA

20 17 m. birželio 7 d.

Kaunas

Patvirtinu, kad mano, **Rūtos Partauskaitės**, baigiamasis projektas tema „Fotoninių srautų poveikio kontaktinių lęšių degradacijai tyrimas" yra parašytas visiškai savarankiškai ir visi pateikti duomenys ar tyrimų rezultatai yra teisingi ir gauti sąžiningai. Šiame darbe nei viena dalis nėra plagijuota nuo jokių spausdintinių ar internetinių šaltinių, visos kitų šaltinių tiesioginės ir netiesioginės citatos nurodytos literatūros nuorodose. Įstatymų nenumatytų piniginių sumų už šį darbą niekam nesu mokėjęs.

Aš suprantu, kad išaiškėjus nesąžiningumo faktui, man bus taikomos nuobaudos, remiantis Kauno technologijos universitete galiojančia tvarka.

(vardą ir pavardę įrašyti ranka) *(parašas)*

CONTENTS

LIST OF FIGURES

LIST OF TABLES

ABBREVIATIONS

CBMA - *carboxybetaine methacrylate*

CL – contact lens

CT - computed tomography

DIRP- diagnostic intervention radiological procedures

Dk/t - Oxygen transmissibility

HEMA – h*Hydroxyethylmethacrylate*

ICRP - International Commission on Radiological Protection

IR - Interventional Radiology

MF - multifocal contact lenses

MPC - *2-methacryloyloxylethyl phosphorylcholine*

MRI - magnetic resonance imaging

OSL - optically stimulated luminescent dosemeter

PEG – *polyethyleneglycol*

PTA - percutaneous transluminal angioplasty

TIRP - therapeutic intervention radiological procedures

TLD - themoluminescence dosemeter

Partauskaitė, Rūta. *Investigation of photon induced degradation of contact lenses*. Master's Final Project / Head Assoc. dr. Judita Puišo; Kaunas University of Technology, Mathematics and Natural Sciences Faculty.

Field of Science and areas: Biomedical sciences Medicine and Health.

Key words: intervention medicine, eye protection, contact lenses, light transmission, absorption.

Kaunas, 2017. 70 p.

SUMMARY

Contact lenses have long no longer news. Their material and design development is constantly changing, as newer technology improves and previous contact lenses constantly evolving. Not surprisingly, the lenses are increasingly replacing glasses and medical staff including - it does not interfere, not cause aberrations, are comfortable in most situations. This work has studied the effects of X-ray radiation to the contact lens optical properties. Three different types of lenses: spherical, astigmatic and multifocal lenses were used in this study. Contact lenses transmittance and absorbance were investigated by UV-VIS spectrometer before exposure and after X-ray exposure. We also verified the change in optical properties of the lens during storage in glucose solution (5%).

The results show, that X-ray irradiation change contact lenses optical properties. Transmittance of contact - lens after exposure by X-ray was – decreased. Dose response curve of contact lenses was used for dose estimation. Also, results showed that changes in the characteristics of optical lenses is also affected by storage conditions.

Partauskaitė, Rūta *Fotoninių srautų poveikio kontaktinių lęšių degredacijai tyrimas*. Magistro baigiamasis projektas / vadovas doc. dr. Judita Puišo; Kauno technologijos universitetas, Matematikos ir gamtos mokslų fakultetas.

Mokslo kryptis ir sritis: Biomedicinos moklsai, Medicina ir sveikata.

Reikšminiai žodžiai: *intervencinė medicina, akių apsauga,kontaktiniai lęšiai, šviesos pralaidumas, absorbcija.*

Kaunas, 2017. 70 p.

SANTRAUKA

Kontaktiniai lęšiai jau seniai nebėra naujiena. Jų medžiagų ir dizaino raidą nuolat keičiasi, nes naujesnės technologijos pagerina ankstesnes ir kontaktiniai lęšiai nuolat tobulėja. Nenuostabu, kad lęšiai vis dažniau pakeičia akinius ir medicinos darbuotojų tarpe - jie netrukdo, nesukelia aberacijų, yra patogūs daugumoje situacijų. Šiame darbe buvo tiriamia, kokią įtaką rentgeno spinduliuotė daro kontaktinių lęšių optinėms savybėms. Tyrimui pasirinkome tris skirtingas lęšių rūšis: sferinius, multifokalinius ir astigmatinius lęšius. Naudojantis UV-VIS spektrometra patikrinome lęšių šviesos pralaidumą prieš apšvitą ir po apšvitos. Šiame darbe taip pat nustatyta kaip keičiasi lęšių optinės savybės juos saugant gliukozės tirpale (5%).

Iš gautų rezultatų seka, kad rentgeno spinduliai lęšių optinėms savybėms daro įtaką - lęšių Iš gautų rezultatų seka, kad rentgeno spinduliuotės veikiami kontaktiniai lęšiai praranda savo skaidrumą didėjant apšvitos dozei. Panaudojant optinio tankio priklausomybes nuo apšvitos dozės nustatytos apšvitos dozės, kuriomis buvo apšvitinti kontaktiniai lęšiai. Nustatyta, kad kontaktinių lęšių skaidris priklauso ne tik nuo apšvitos dozės, bet ir nuo jų saugojimų aplinkos sąlygų.

INTRODUCTION

Many of patient and doctors, exactly in interventional radiology, usually are using some vision correction as contact lenses. Modern interventional radiology is a perfect example of how advances in medical technology is changing clinical practice diagnostics and treatments. While the X-ray surgical operations and medical use of protective equipment, eye lens remains adequately immune.

The aim: to analyze the properties of contact lenses changes after exposure to ionizing radiation, to find the effect of ionizing radiation to contact lens optical characteristics and apply this knowledge to retrospective dosimetry.

Objectives:

1. Evaluate the lens characteristic and choose the lenses, that could be applied to retrospective dosimetry.
2. Evaluate the influence of X-ray irradiation on contact lenses optical properties.
3. Create dose response curve of contact lenses.
4. Apply dose response curves of contact lenses for expose dose estimation.

1. LITERATURE REVIEW

1.1.X-RAY and Interventional Radiology

X-rays have a wavelength ranging from 0.01 to 10 nanometers and energies in the range 100 eV to 100 keV. X-rays are roughly classified into two types: soft X-rays and hard X-rays (1). One of the most common and beneficial uses of X-rays is for medical imaging. X-rays are produced when highly energetic electrons interact with matter and convert their kinetic energy into electromagnetic radiation.

X-rays can be generated by an X-ray tube for medical diagnostic and treatment procedures. A vacuum tube use a high voltage to accelerate the electrons released by a hot cathode to a high velocity. The high velocity electrons collide with a metal target, the anode, creating the X-rays. However X-ray photons have enough energy to ionize atoms and broken molecular bonds. The X-ray generator allows to manage of the x-ray output within the rejection of voltage, current, and exposure time. These summand works in consensus to produce a beam of x-ray photons of well-depict penetrability, intensity, and spatial widening.

The voltages used in diagnostic X-ray tubes range from roughly 20 kV to 150 kV and thus the highest energies of the X-ray photons range from roughly 20 keV to 150 keV [1].

„Interventional radiology (IR) refers to a range of techniques which rely on the use radiological image guidance (X-ray fluoroscopy, ultrasound, computed tomography (CT) or magnetic resonance imaging (MRI)) to precisely target therapy" [2].

1.1.1. Overview of Interventional radiology procedures

Interventional radiological procedures are divided into two main groups:

- diagnostic intervention radiological procedures (DIRP);
- therapeutic intervention radiological procedures (TIRP).

„DIRP is a major test of the determination of peripheral vascular disease.

TIRP also are divided into two main types:

- Percutaneous transluminal angioplasty (PTA);
- Embolization" [3].

„Percutaneous transluminal angioplasty (PTA) is a procedure that can open up a blocked blood vessel using a small, flexible plastic tube, or catheter, with a "balloon" at the end of it“[4]. During procedure normal blood flow is restored when the tube is in place - it inflates to open the blood artery, or vessel. (Fig.1.)

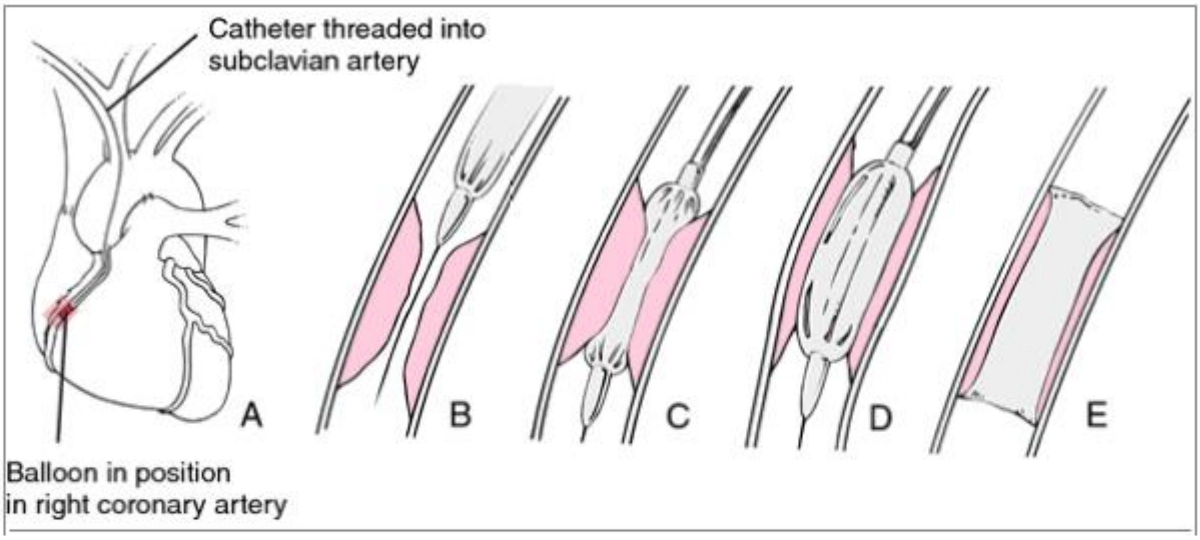

Fig.1. Percutaneous transluminal coronary angioplasty (PTCA). A, Balloon-tipped catheter positioned in blocked artery. B, Balloon is centered. C, Balloon expands to (D) compress blockage. E, Artery diameter opened. From Polaski and Tatro, 1996. [5].

Percutaneous transluminal angioplasty is a comparatively new way employed in the treatment of stenosis or occlusion of peripheral arteries. Short-term results have been excellent while the long-term success rates still have to be determined. Shunning surgery and its guard risks, the procedure has splendid value in the dilatation of allocated lesions. Anyway, PTA and surgery are complementary, not contending modes of therapy. In that case, PTA supplements the traditional therapy of peripheral vascular disease, which refuse reconstructive surgery.

„Embolization is a minimally invasive treatment that occludes, or blocks, one or more blood vessels or vascular channels of malformations (abnormalities)“ [6]. In this procedure are used x-ray imaging and a contrast substance. The interventional radiologist inserts a catheter through the skin into a blood vessel and advancement it to the treatment site, this is how radiologist can visualize the blood vein (Fig.2). A synthetic material or medication called an embolic agent is t inserted through the catheter and positioned within the blood vessel or malformation where it will remain permanently.

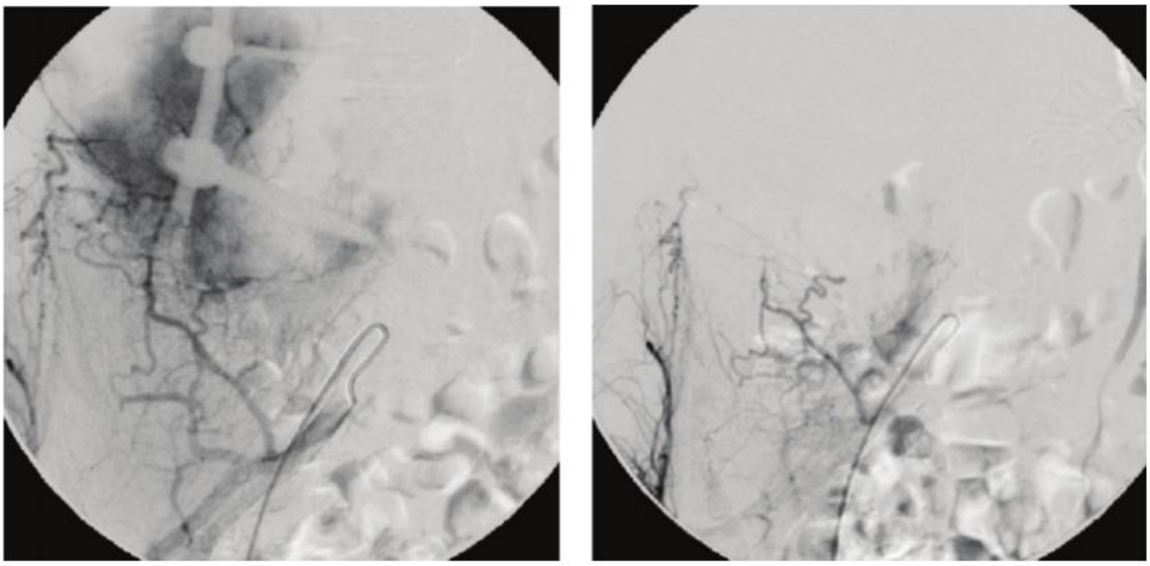

Fig.2. Angiogram before and after selective arterial embolization. (a) Preembolization angiogram of the right internal iliac artery demonstrating a massive hypervascularization of the giant cell tumor (case 6). (b) After embolization with embozene microspheres (250 μ m) a complete devascularization of the giant cell tumor was achieved [7].

Embolization is an exceptionally comprehensive procedure used in almost all vascular and non-vascular systems to treat a broad range of pathology.

The band of disease processes and organs liable to interventional radiology is wide and includes vascular, hepatobiliary, gastrointestinal, genitourinary, musculoskeletal, pulmonary, and neurological conditions. Interventional radiology is a new branch of medicine, closely related to many other clinical areas as:

- Vascular Surgery
- Oncology
- Endocrinology
- Neurology
- Neurosurgery, etc.

Work in that area greatly increases the different profiles of patient diagnosis and treatment options.

Interventional radiology offers minimally invasive image guided therapy for a growing range of vascular and non-vascular diseases. Interventional radiologists have considerable clinical satisfaction from making a real difference to patient lives.

1.1.2. IR workers monitoring

Employees who work with sources of ionizing radiation and the surroundings must be carried out in individual exposure monitoring in accordance with the Lithuanian hygiene standard HN 73: 2001 "Basic Standards of Radiation Protection".

Employee exposure legislation:

- Lithuanian Republic Radiation Safety Act.;
- Lithuanian Minister of Health in 2001. 21 December. Order No. 663 of the Lithuanian Hygiene Norm HN 73: 2001 „Basic Standards of Radiation Protection“ approval;
- Radiation Safety Director of the Centre in 2003. 16 June. Order No. 19 „On the use of personal protective equipment when working with sources of ionizing radiation rules“;
- Radiation Safety Director of the Centre in 2015. 24 July. Order No. V-53 „On Radiation Safety Director of the Centre in 2007. 16 November. order no. 63 on the exposure of workers and jobs in the monitoring rules for the approval of the amendment”.

Trainees, without exception, have to receive exposure monitoring in all the following procedures:

1. „Imaging-guided biopsy and drainages;
2. Venous access placement;
3. Diagnostic peripheral angiography;
4. Peripheral arterial revascularization techniques;
5. Endovascular repair of abdominal and thoracic aneurysms;
6. Visceral/renal arteriography;
7. Diagnostic neuroangiography;
8. Embolization techniques
    a. Those used to treat traumatic bleeding, gastrointestinal bleeding, portal vein embolization, or fibroid tumors, and
    b. The proper use of microcatheters and wires should be included in this experience;
9. Percutaneous transhepatic cholangiography, biliary drainage, and biliary stent placement;
10. Nephrostomy tube placement;
11. Gastrostomy tube placements;
12. Dialysis fistula/graft evaluation and intervention;
13. IVC filter placements;

14. Vascular thrombolysis and thrombectomy techniques;

15. Interventional oncology therapies such as ablative and trans-catheter therapies“[8].

1.1.3. IR monitoring and protection.

IR procedures leaded aprons is covered employee chest, waist, thighs legs and an arm and lower leg virtually unprotected and exposed scattered X-ray radiation. Radiation exposure to the eyes protection, in the professional exposure determination, can be widely divided into three categories [9]:

1. „exposure to beta radiation that can be effectively shielded by wearing protective eyewear containing plastic lens (Perspex™ or equivalent);
2. exposure to x-rays that can be shielded by wearing protective eyewear with lead-glass lenses;
3. exposure to gamma radiation that is so penetrating that protective eyewear would be too heavy or bulky to wear”.

It is known that the eye lens is one of the most radiosensitive organ in the human body. This has led to certain dose limits for the lens. Cataract has been seen as a deterministic effect, i.e. there is a doorstep below which no damage occurs. For individual monitoring aim the characteristics of a proper eye lens dosemeter should be: the capability to measure the appropriate operational quantity, a respective response with admissible accuracy to a diversity of angles and energies collided in the scattered field of workplaces and stay comfortable, as it is position is normally as close as possible to the eye of the operator. The physicians must wear the lens dosimeter (Fig.3). „The basic structure of the dosemeter is the same: a thermoluminescent detector, sufficient filtration and a holder to help the dosemeter to be placed as close as possible to the eye lens“ [10].

Fig.3 TLD in eye dosimetry [11].

The promotion of the dosemeters modify a lot and belong on how appropriate and convenient they are when worn by the doctors or operators. “The Personal Dosimetry Service of Public Health England provides eye dosimetry based on alternative forms of themoluminescence dosemeter (TLD): the whole body TLD and the headband dosemeter” [12]. TLD as and optically stimulated luminescent dosemeter (OSLD), can be used for direct measurements of dose during radiotherapy. Small detectors are able to measure the delivered dose directly that is so important in IR procedures. OSL dosimeters function in the same way as TLDs, but are made of a different material. The difference is that the readout is done by stimulating the dosimeter with a green laser or light emitting diode. They are also less sensitive to temperature, which can be an advantage during in vivo measurements, and experience less fading over time. “The dosemeters are designed to measure doses from gamma and X-radiations to the lens of the eye in terms of the radiation quantity Hp[3], the dose equivalent at a depth of 3 mm, as required by the Health & Safety Executive (HSE)” [12]. TLD assure the good energy – response and broad dose range between at least 10 μSv and 10 Sv. OSL dosemeter has broad base response and capable of detecting low doses as 10 mSv. The OSL dosimeter can be reuse several times. It can differentiate between static and dynamic exposures.

Since workable use of ceiling suspended screens and allowance of lead glasses- operator have to be responsible on options for protection. Workers all the time are protecting chest, neck and the other parts of the body. However, protection of lens of the eye isn't so easy. Table 1 presents protection recommendations to decrease on the annual dose.

Table 1. Proposed dose levels for guidance on use of protection for the eyes [13].

Tissue	Annual unprotected dose (mSV)	Protection recommendations
Eyes	3-6	Ceiling suspended screens should be used where available. Protective eyewear may be considered where there is no other protective device.
Eyes	>6	Protection essential. Both ceiling suspended shield and protective eyewear should be considered and at least one form used. Training should be given in use of ceiling-suspended screens where these are provided

The medical profession in IR procedures, in order to protect the lens of the eye from exposure, use appropriate protective measures:

1. Ceiling suspended screens:
    1.1. overhead suspension shields;
    1.2. mobile screens and workstations;
2. Protective eyewear.

Overhead suspension shields can be used to protect at least two persons. Usually it is much too small and uncomfortable to use, even when it can rotate 360º degrees (Fig 4). „Lead-glass barriers are so small (usually 16 x 12 inch or 20 x 16 inch) that when you move, you must also move the barrier to avoid exposure" [14]. This is system allowing the shield to be stored away from the x-ray tube when not in use.

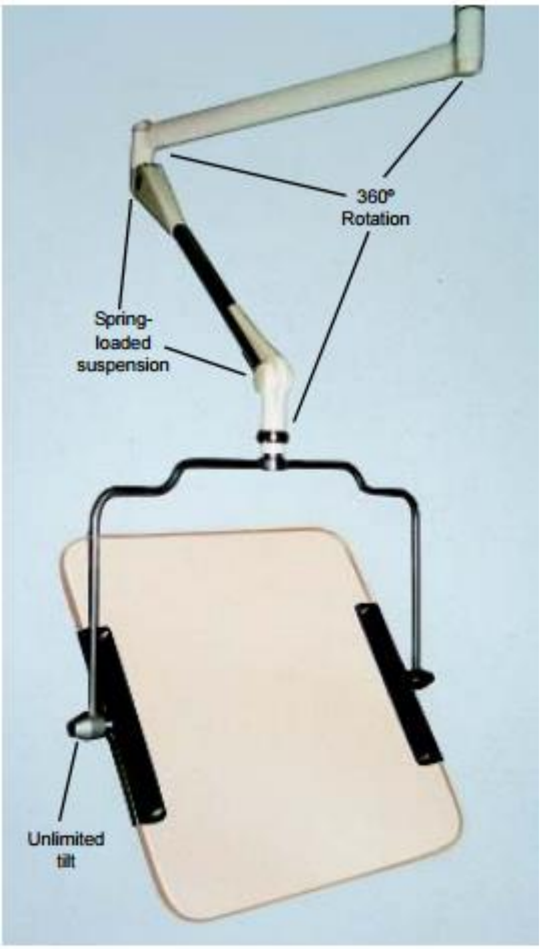

Fig. 4 Overhead lead-glass barriers construction [14].

Lead glass shield can be with 0,5mm - 2,0mm pg equivalent, with protective frame around the lead-glass shield or panoramic visibility.

Mobile screens also can be divided as panoramic mobile screen, standard mobile screens and special purpose mobile screens (Fig. 5). These screens are particularly useful in departments where space may be an issue.

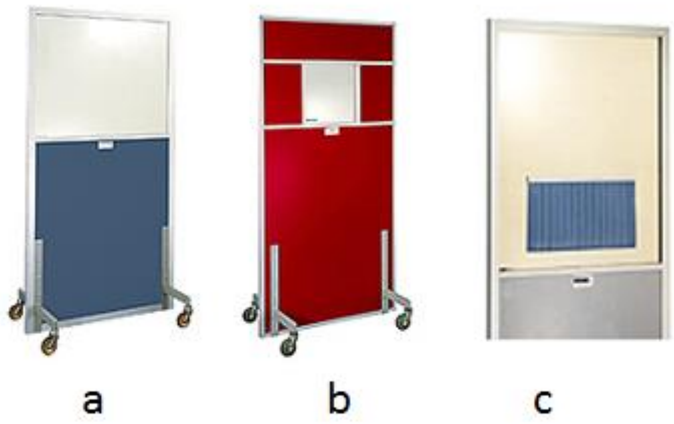

Fig.5. Types of mobile screens: a) panoramic mobile screen, b) standard mobile screen, c) special purpose mobile screen (15).

Protective screens can be different weight, width and lead equivalent. Differences of screens are presented in Table 2.

Table 2. Description of different protective screens [15].

		Panoramic mobile screen	Standard mobile screen	Special purpose mobile screen
Lead (mm, Pb)		1,5 – 2,0 (depends on model)	1,5 - 2,0 (depends on model)	0,5 – 1,32
Overall (mm)	Height	2000	2000	200
	Width	850-1250 (depends on model)	900-1000	-
Window (mm)	Height	800	400	800
	Width	800-1200 (depends on model)	400	-

Selection of protective screen depends on many factors such as exposure dose during procedure, specifics of procedure, a size of the room and so on.

Protective eyewear is most popular and helpful in interventional medicine. Currently there are several types of goggles, according to their size, partially protected area, specific lens type (single vision, standard bifocal or multifocal design), etc. (Fig. 6).

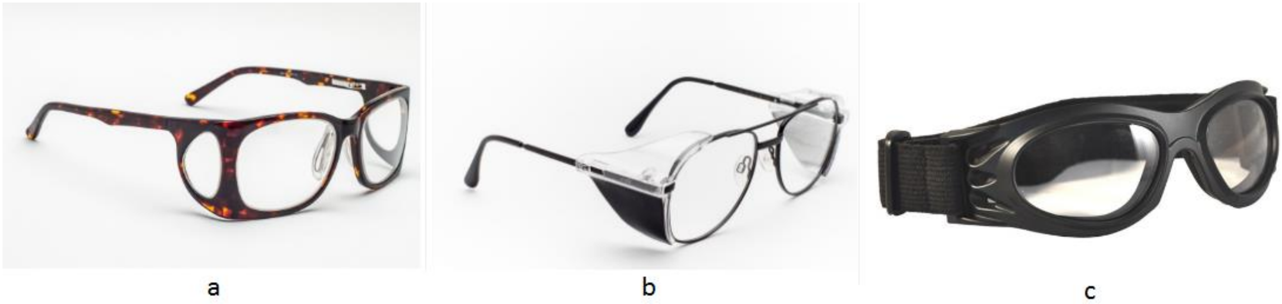

Fig. 6 Radiation protective glasses: a) Phillips Model RG-52 frame features a silicone no-slip, unifit bridge with adjustable nose pads and lenses are with 0,75mm lead equivalency; b) Phillips Model 100 made of durable non-corrosive stainless steel lenses with 0,75mm lead equivalency and 0,50mm lateral production; c) Phillips Model RK2 flame-resistant elastic headband is adjustable, lenses with 0,75mm lead equivalency [16].

Various models of protective eyewear with different form, sizes and lead thickness must be estimate before their use since penetrating and higher energy gamma rays. The estimation should involve radiographic or fluoroscopic survey to approve that the side shielding is ample and trial by the potential wearers to assure the proximity of the fit and the greatest comfort in wearing.

1.1.4. Annual doses of IR employees

IR involved in procedures for employees, especially physician, receive much higher doses of external radiation compared with other categories of workers. For this reason, this category of workers increased risk of developing determined effects (skin aging, eye cataracts, hands hair loss, etc.) or random effects (cancer). The International Commission on Radiological Protection (ICRP) have recommended that for occupational exposure a dose limit for the eye lens of 20 mSv in a year, averaged over defined periods of 5 years, should be applied, with no single year exceeding 50 mSv. In the occupational exposure setting, radiation exposure to the eyes can be widely divided into three categories[9]:

1. „Exposure to beta radiation that can be effectively shielded by wearing protective eyewear containing plastic lens (Perspex™ or equivalent);
2. exposure to x-rays that can be shielded by wearing protective eyewear with lead-glass lenses;
3. exposure to gamma radiation that is so penetrating that protective eyewear would be too heavy or bulky to wear ".

Many IR cure are minimally predatory alternatives to open and laparoscopic surgery. Interventional radiologists are trained in radiology and interventional therapy. In this case them work is including kind of radiation dose as. One year total dose of employers [17]:

- “2.0 mSv – interventional cardiologist and radiologist;
- 1.5 mSv – conventional radiology mSv –radiographers;
- 0.5 mSv – non radiographic /radiological staff (e.g. nurses, students)”.

The risk to get cancer caused ionizing radiation increase by received dose. Cells genetic changes depends on many factories as: on the individual's age at the time of exposure, gender, exposure intensity and time.

Radiation protection for interventional radiology staff is an important issue. Radiological Limits give radiation limits for workers, apprentices, students and public (Table 3). „The annual dose limit for deterministic effects to the skin is set to 500 mSv averaged over $1cm^2$ area of skin regardless of the area exposed. The annual dose limit for deterministic effects to the eye lens is set to 150 mSv. When 1/10 of the limit is reached, it is legally required that doses are routinely monitored “[18].

Table 3. Occupational Exposure of apprentices, students and workers, compered between new and old dose limitations [19].

Planned exposure situations					
Occupational exposure of workers		Occupational exposure of apprentice & students		Public exposure	
>18 years		16-18 years			
Equivalent dose to the lens of the eye:					
New	Old	New	Old	New	Old
20 mSv per year averged over 5 consecutive years, and 50mSv in any single year.	150 mSv in a year.	20 mSv in a year.	50 mSv in a year.	15 mSv in a year.	15 mSv in a year.

1.2.Contact lenses characteristics

In our days contact lens is a modern vision correction tool. Comfortable wearing and easy care already changed lives of million people who is necessary vision correction. Contact lenses (CL) – small and thin optical lens that are placed directly on the cornea. These materials are biocompatible. There are not cause problems due to the reaction with human tissue. They allow enough oxygen to get into the eye what give us as much comfort as possible. There are many different types of contact lenses, which differ among themselves in their characteristics, uses, changing them, carrying time and the effects of corneal parameters (Fig.6.).

Contact lenses are classified:

1. In accordance with the materials of which they are made;
2. In accordance with the frequency (time limit after which contact lenses replaced with new ones);
3. According carrying mode (full-time, flexible, elongated, continuous);
4. In accordance with its design (spherical, toric, multifocal);
5. The degree of transparency (transparent, colored, fancy).

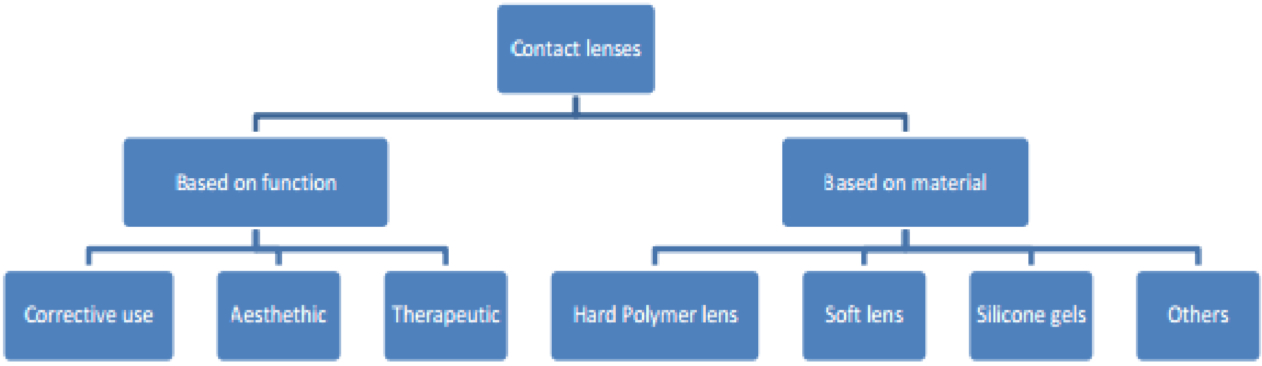

Fig.6. Schema of contact lens classification [20].

All lenses are provided with a chromophore to absorb UV light and some also absorb violet or blue light to protect the retina. In the contact with the eye, the material has to be enough hydrophilic to hold the normal hydration of the tear film and oppose deposition of tear proteins and lipids.

1.2.1. In accordance with the materials of which they are made. Hard and soft contact lenses.

Hard contact lenses are used in complex cases (high degree of correct astigmatism at keratoconus) and orthokeratology. „In 1968, The Food and Drug Administration classified soft lenses as a drug. Between 1954 and 1970, as soft contact lenses were improving and developing in design and materials, poly(methyl methacrylate) (PMMA) hard contact lenses were depreciating in their use" [21]. The hard CL were smaller, covered only the cornea. They used up to 16 h per day. These lenses have been permeable for oxygen and sparked numerous complications. Now gas impermeable hard lenses already obsolete.

Current hard CL are made from polymers that provide high oxygen permeability. Such lenses are called gas-permeable hard contact lenses (Fig.7). Solid CL advantage is that they are a good visual brightness and they can control the progression of myopia to a certain degree. These lenses are made of materials that do not contain water, which means that one pair of proper cleaning and maintenance, can serve for many years.

Fig. 7. Hard and soft contact lenses [22].

Gas-permeable hard CL are made of materials that do not contain water, which means that one pair of proper cleaning and maintenance, can serve for many years. Is currently knowing a wide diversity of designs and materials for gas-permeable hard CL that provide for safe fitting and usage, which allows to be first choice lenses, with frequent check-ups recommended.

Silicone lenses are made of a silicone elastomer or silicone hydrogel. "Hydrogels are a generic term for highly crosslinked polymers that have a nanoporous internal structure that is filled with aqueous media." [23]. The first pplymer used for a hydrogel lens was h*ydroxyethylmethacrylate* (HEMA). However, Silicone-hydrogel materials, silicone rubber are created complex with hydrogel monomers. The silicone created specially, for lens materials gives especially high oxygen permeability. The hydrogel part gives lighter flexibility, wettability and fluid transport, that aids lens motion. The silicone elastomer lenses for extremely high oxygen permeability and has previously have been used for therapeutic purposes. “Oxygen transmissibility (Dk/t), which is lens specific for all CLs, is directly dependent on both the Dk of the CL material and the reciprocal of its individual thickness (t) profile” [24]. The oxygen permeability of hydrogel lenses is proportional to the amount of water in them. However, in all hydrogel lenses, even with large water content (75%) of the lens has an oxygen permeability (Dk / t) does not exceed 40, and secure continuous lens wear Dk / t must be at least 87th. In this case, most helpful are silicone – hydrogel contact lenses. Silicone hydrogel (called *etafilcon A*) structure is composed of two components: a silicone hydrogel (Fig.8.).

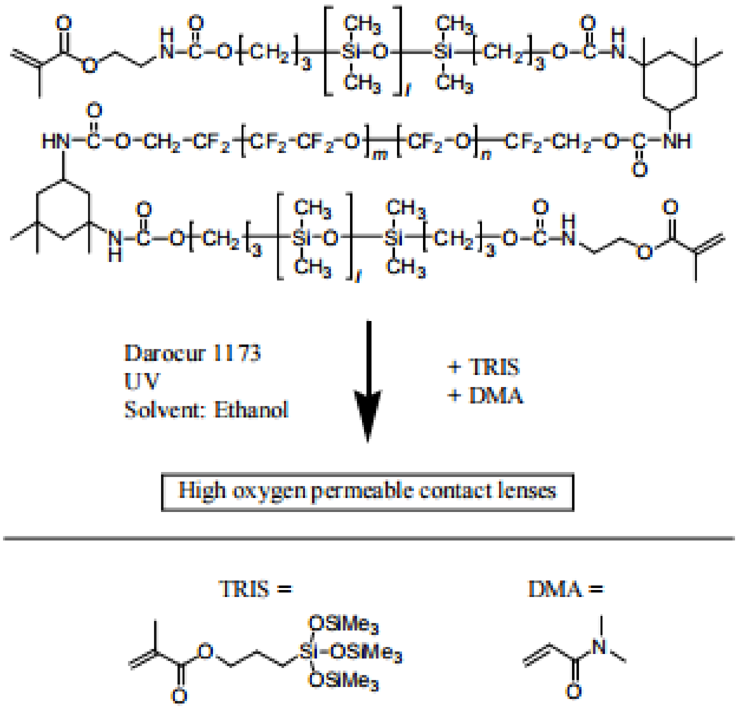

Fig.8. Synthesis and formulation of a silicon hydrogel contact lenses [25].

A hydrogel component of polymer is required for compatibility with ocular tissue, silicon - corneal oxygen delivery falling from the atmosphere through the contact lens. “Polyhydrophilic polymers, including *polyethyleneglycol* (PEG), polysaccharides, and polyamides, and polyzwitterionic polymers such as *2-methacryloyloxylethyl phosphorylcholine* (MPC) and c*arboxybetaine methacrylate* (CBMA) have been employed in the development of bio-antifouling substrates to reduce protein adsorption and biofilm formation on contact lenses “[26]. The CL oxygen permeability through the lens is many times higher than the maximum oxygen permeability in hydrogel lenses. There are also known a new kind silicone hydrogel contact lens material – as *comfilcon A*. “Silicone hydrogel materials have Dk values far in excess of the Dk achievable with hydrogels “[24]. New contact lenses are made from fluoropolymer. This polymer delivers superior oxygen. Gas-dating is related to the intermolecular spacing size, which carry gas molecules, gas solubility. Silicone monomers are most frequently used because of their molecular structure creates a more open polymeric structure [9]. The addition of fluorine gas increases the solubility of the polymer and a little silicone counteracts a tendency to bind particles repellent (such as lipid slime) that comes into contact with the surface of the contact lens.

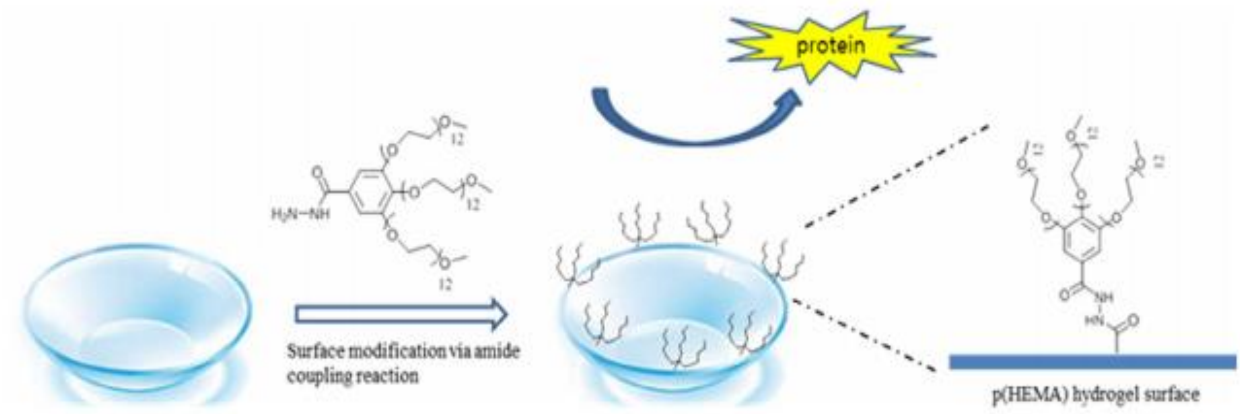

Fig.9 Schematic representation of branched PEG-functionalized hydrogel lenses exhibiting protein adsorption resistance [26].

The differences between silicone hydrogel contact lens materials and simple hydrogels are very large. They can be widely divided into diversity between the gross properties and those attributable to the surface. Silicone hydrogel CL assist minimize problems like redness, dryness, corneal infections and swelling of the cornea, these lenses accumulate less plaque proteins, but more attracted to fatty deposits. These contact lenses increase the hight oxygen transport to the cornea, that improves eye health and best comfort.

1.2.2. In accordance with the frequency

Depending on the frequency used recommended CL are:

- disposable - these lenses serve only 1 day because in the morning is placed in the eye, and in the evening removed. This is the healthiest CL, do not require additional maintenance;
- frequent planned replacement lenses - changed every 2 weeks or more;
- planned change - they change after period, mainly due to the lens surface of the build-up of sediment. Optimal CL Carrying maturity 1 month, therefore, the most and is produced

monthly CL. It is also every 3 and 6 months replacement contact lenses. They are portable enough rare.

– traditional - these lenses are replaced every 6-12 months. They are practically no longer used.

1.2.3. According carrying mode

„Daily contact lenses in the morning placed in the eye in the evening removed and discarded" [27]. Wearing time of CL should not be longer than 11 hours. This requirement is applied to all type hydrogel lenses. Daily wear contact lenses for the production of both high as well as low oxygen permeability material. Prolonged wearing mode of contact lenses wears for 6 days without taking them out of sight at night. After that, it is necessary to remove the contact lenses, disinfect and soak them clean and give the eyes a rest.

The flexible carrying mode allows sometimes with daily wear contact lenses to sleep mode for 1-2 nights. Prolonged and flexible carrying mode is recommended only for silicone hydrogel contact lenses with high oxygen permeability (Dk / t = /> 125).

Carrying continuous mode of contact lenses wear up to 30 days, without removing them at night. This mode is recommended to wear only some of the silicone hydrogel contact lenses

1.2.4. In accordance with its design

Most of the market is CL spherical design and for the correction of myopia and hyperopia. The CL of the optical surface area is close to a spherical shape (Fig.10). In ensues over the entire surface is the same power (diopter unchanged). For the correction of ametropia also can be used and toric contact lenses.

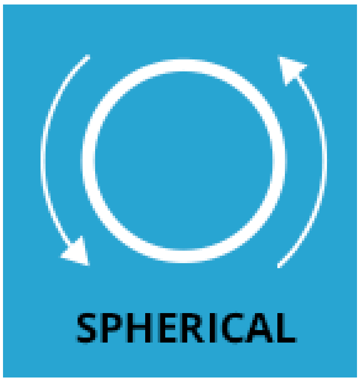

Fig.10. Spherical contact lenses have the same power in all meridians, so it remains stable and does not move in the eye blinking [28[.

Toric contact lenses generally used to describe specially designed soft CL that correct astigmatism. „Toric soft contact lenses require rotational stability for consistent visual performance "[29]. Toric lenses have different powers in different meridians of the lens. These lenses technology uses "fixation" area that astigmatic lens in the eye to its correct position (Fig.11).

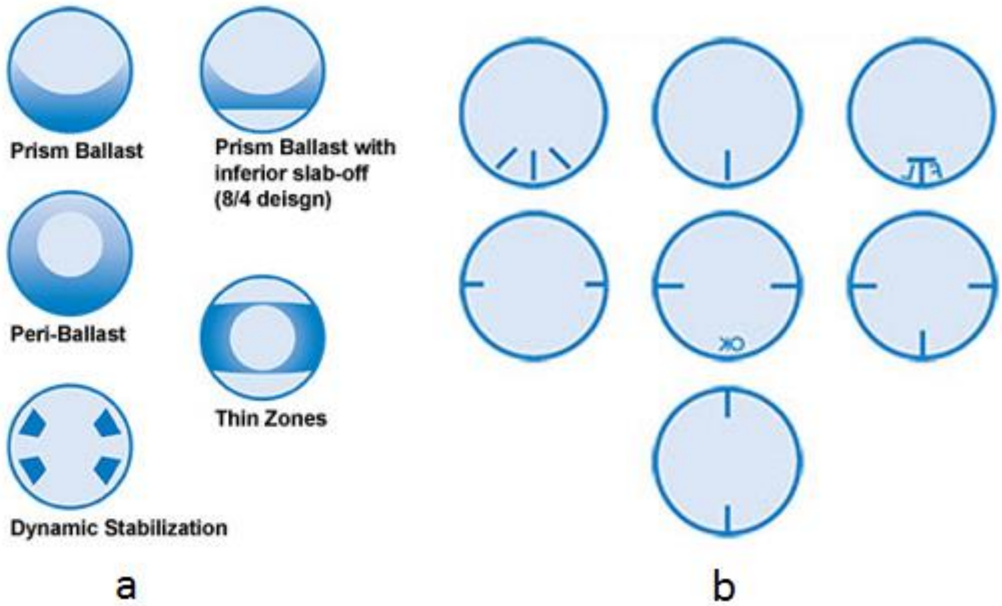

Fig.11. Toric lenses fixations: a) design of fixation, b) various markings [30].

Toric contact lenses have respective markings which optometrist or ophthalmologists can judge whether the lens in the eye is right axis.

Presbyopia (age changes in the lens of the eye drop adaptability bright shows a close distance) adjustment is used multifocal contact lenses (MF). They can be spherical and torical. MF lenses structure incorporating an additional optical zone (or zones) correcting intermediate, distance and near vision pupil (Fig.12). MF lenses come in types: concentric ring designs, aspheric designs and translating designs.

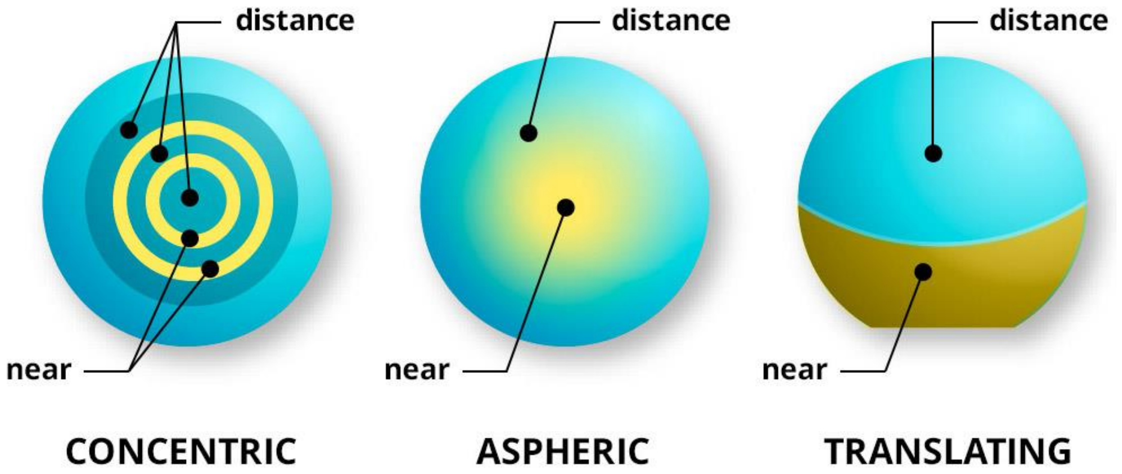

Fig.12. Designs of MF contact lenses. In concentric designt the distance prescription is in the center and is covered by rings of near and far power. In aspheric design the near and distance prescriptions are both in front of the pupil. In this translating design the near power is on the bottom [31].

The most popular is concentric and aspheric designs, because user felt comfortable, flashing lens does not move and does not cause aberrations and instability feeling.

1.2.5. The degree of transparency (transparent, colored, fancy) of CL

Contact lenses are also different in colors. Eye color intensifier is only for beauty - they can also be designed and vision correction. Colored lenses are made from hydrogel, they can be worn from month to three months daytime mode (night must be removed). In addition, it should be noted that studies show that decorative lenses worsens visual functions, namely sharpness, contrast, narrowing of the visual field. It is therefore not recommended to wear them consistently.

1.2.6. CL storage conditions

Lenses is on the surface of the eye, both cold and heat does not significantly affect, as lenses remain similar temperature as the surface of the eye. However, their storage to meet certain requirements, as this instrument for medical purposes. Wearing contact lenses on the surface of the environment falls and settles various impurities, as well as - protein deposits. All this unnecessary "baggage" can not only impede visibility, but also irritate the eyes - the red and starts itching, foreign body sensation occurs. Thus, one of the lenses in the solution functions is to remove the debris while maintaining the cleanliness of contact lenses, and - and hence the good eye condition. CL liquid lens also has disinfection function - it neutralizes a variety of bacteria and micro-organisms. It can cause eye diseases, e.g., conjunctivitis (eye inflammation). This reduces the chance that contact lenses in any way damage the eyes. The most important is do not keep the cold lens, for example. refrigerator or freezer because freeze- warm can damage the lens and increase the integrity of the ocular surface risk. Also, do not keep the lens containers warmer than room temperature because it can promote bacterial growth and the risk of infectious complications.

There are many kinds of contact lens solution. They are all different in their composition, the validity of the opening term storage conditions. Not all the solution was for each type of lenses. Modern solutions divided into two main areas:

a) Multifunctional
b) hydrogen peroxide solution.

Universal multifunctional solution performs multiple functions: cleans, moisturizes, disinfects, they kept in contact lenses as well as they can also rinse the lenses before placing them in the eye. These solutions are easy to use, because everything fits. However, this solution contains preservatives that can cause allergic reactions in the eyes.

For example, according to the manufacturer, the solution may consist of:

- Bausch & Lomb (USA): Hyaluronate, Sulfobetaine, Poloxamine, Boric Acid, Sodium borate, Edet Disodium, Sodium Chloride, Polyaminopropyl biguanide Polyquaternium;
- AMO ((Ireland): Polyhexamethylene biguanide (0.0001% Poloxamer 237, Edet Disodium, Sodium Chloride, Water (Purified);
- ALCON (USA): Citrate / borate buffer, Sodium Chloride, edetic Disodium (0.05%) Polyquaternium 1, RLM 100, Tetronic 1304[th].

Meanwhile, hydrogen peroxide solution for a contact lens disinfecting and storage. It does not contain preservatives, so the eyes are the healthiest. Sanitizes and cleans this solution in 3% hydrogen peroxide. The solution is actually very good clean contact lenses formed from plaque, but not suitable for rinsing and cleaning process in a special tray takes 6 hours until the hydrogen peroxide is saline. Its composition may vary according to manufacturer. Examples:

- ALCON (USA): hydrogen peroxide of 3% phosphonic acid, sodium chloride, phosphate, Poloxamer, HydraGlyde * Moisture Matrix (EOBO-21 * - polyoxyethylene-polyoxybutylene).

1.3.Surfactant

Many surfactants have a few uses what usually is confusing. The most acceptable and scientifically sounds arrangement of surfactants is based on their dissociation in water. „Surfactant, also called surface-active agent, substance such as a detergent that, when added to a liquid, reduces its surface tension, thereby increasing its spreading and wetting properties“ [32].

The surface-active molecule has to be parcel hydrophilic and parcel lipophilic. It focus at the interfaces between bodies or drib of water and those of oil or lipids to effect as an emulsifying or foaming agent. Certain surfactants are germicides, fungicides, and insecticides. Fig.13 shows the process how the surfactants are injected to material.

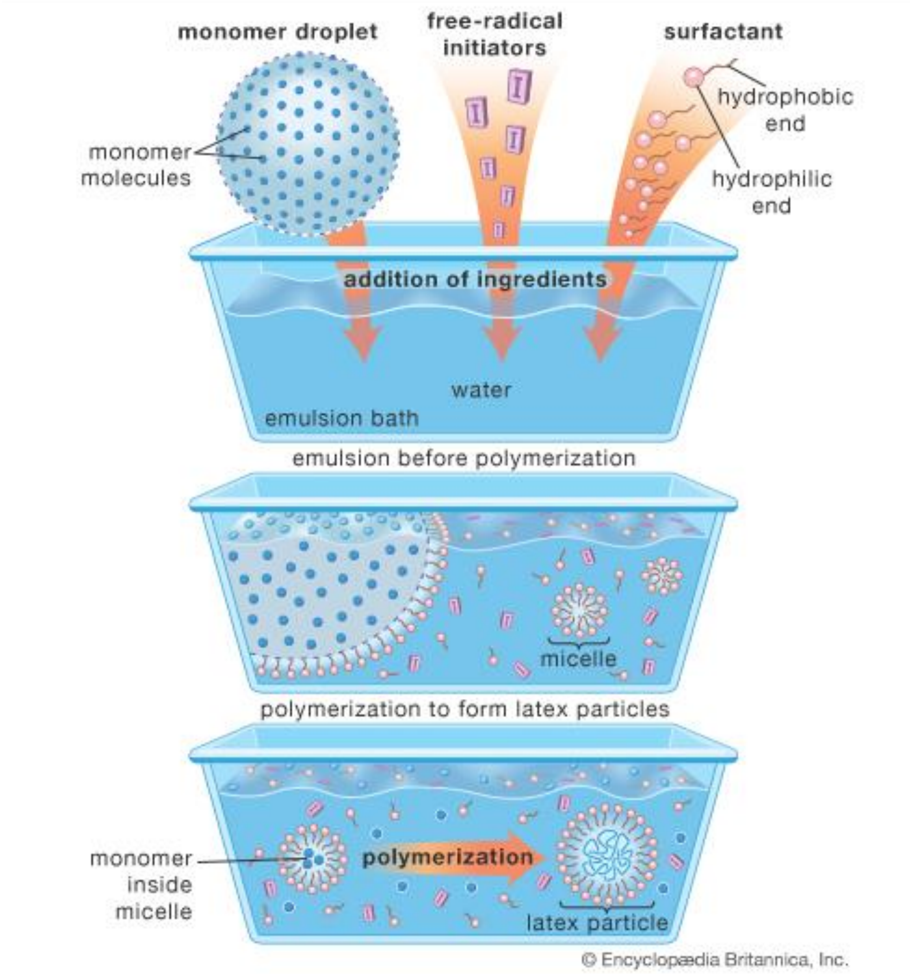

Fig. 13. Schematic diagram of the emulsion-polymerization method. Monomer molecules and free-radical [32].

From the trade point of view surfactants usually are classified according to they applyication. Many surfactants have several ways to use what can give confusion. „The most accepted and scientifically sound classification of surfactants is based on their dissociation in water" [33], (Fig14).:

1. anionic surfactants;
2. nonionic surfactants;
3. cationic surfactants;
4. amphoteric surfactants.

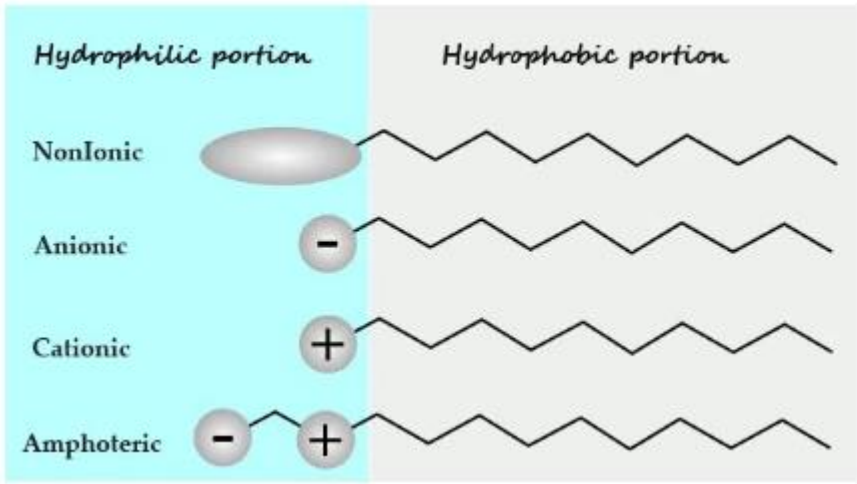

Fig.14. The different types of surfactants [34].

„Anionic Surfactants are dissociated in water in an amphiphilic anion, and a cation, that is in general an alkaline metal ($Na+$,$K+$) or a quaternary ammonium" [33]. Anionic silicone surfactants are prominent to diminish the irritation effects of sulfates. „They include alkyl benzene sulfonates (detergents), fatty acid soaps, lauryl sulfate (foaming agent), dialkyl sulfosuccinate (wetting agent), lignosulfonates (dispersants) etc." [33]. Anionic surfactants have high and excellent cleaning properties. The surfactant is especially good at protecting the dirt away from fabrics, removing residues of tissue softener from fabrics.

Nonionic surfactants as well are found in many cleaning products. „They do not ionize in aqueous solution, because their hydrophilic group is of a non-dissociable type, such as alcohol, phenol, ether, ester, or amide" [33]. The properties of a nonionic surfactant can be adapted partly for a specific use by controlling the comparative amounts of hydrophilic and hydrophobic nature. „They are used to boost and stabilize foam and, depending on the kind, provide conditioning effects on hair and skin" [35]. Nonionic are thick liquids that are sticky to the touch.

Cationic surfactants are less prevalent in cleaning production. „A very large proportion of this class corresponds to nitrogen compounds such as fatty amine salts and quaternary ammoniums, with one or several long chain of the alkyl type, often coming from natural fatty acids“ [35]. Cationic have positively charged ends, which makes them an ideal antistatic.

Amphoteric Surfactants have less used on their own, but act especially well in increase the cleaning effect of anionic and nonionic surfactants. „True amphoteric surfactants are those that exhibit a varying charge, from positive, to negative, on the hydrophilic depending on the pH of the solution in which they are found“ [36]. Amphoteric surfactant help boost foam, improve conditioning and even reduce irritation. They are also used for cleansing products that require mildness.

1.3.1. X-Ray interaction with surfactant

When the X-ray interact with matter there are observed several physical phenomena such as Compton effect and photoelectric effect. The phenomenon, which occurs especially in bright light corpuscular (quantum) properties are Compton effect. 1922. American physicist A. Compton, investigating the short-wave X-ray diffusion in various materials, noted that the scattered radiation wavelength greater than the wavelength of the radiation falling. This electromagnetic radiation of wavelength dispersion increases in time called the Compton effect. “Compton scattering is the process whereby a gamma ray interacts with a free or weakly bound electron (~ >> E~) and transfers part of its energy to the electron“ (Fig.15) [37].

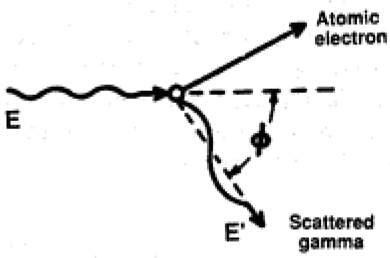

Fig.15 A schema of Compton effect [37].

Photon departs the site of the interaction in a direction different from that of the original photon. “Compton scattering is most likely to occur for gamma rays in the 600-4000 keV range and results in a continuum of scattered gamma ray energies from 250 keV below the highest energy of the incident gamma radiation (Compton gap) down to a minimum value dependent on the energy of the incident radiation” [38]. Compton effect is purely corpuscular phenomenon he describes as well as the elastic collision of two balls. This means that the wavelength increases during Compton scattering can be expressed on the basis of energy and momentum conservation laws. “Compton scattering is similar to the photoelectric effect, in that it involves the interaction of a gamma ray with an atomic electron, resulting in the ejection of the electron from the atom" [38].

The photoelectric effect or photoelectric effect - the electron emissivity induced by of by electromagnetic irradiation (such as visible light or UV radiation) also present in X-ray interaction with mater. "Gamma rays may interact with a bound atomic, electron in such a way that it loses all of its energy and ceases to exist as a gamma ray." [37] (Fig.16).

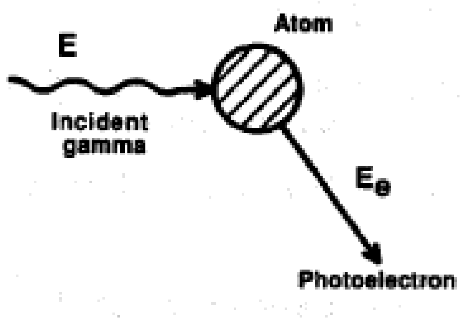

Fig.16. A schematic representation of the photoelectric effect [37].

Photoelectric effect is important for gamma-ray detection whereas the gamma ray provides up all its energy, and the resulting pulse falls in the full-energy peak." The probability of photoelectric absorption depends on the electromagnetic radiation energy, the electron binding energy, and the atomic number of the atom" [37]. This effect is possible only when the photon has adequate energy to overcome the obligatory energy and remove the electron from the atom.

Optical properties of final polymers, such as, gloss, transparency, clarity, colour dependant on the initial polymer physical and chemical properties. Optical properties are dependent on the specific polymer or copolymer material, the formulation (colourants, fillers, plasticizers and other additives) and the crystallinity of the materials. "Ionizing radiation such as γ-rays is even more versatile; it is capable of converting monomeric and oligomeric liquids into solids, but also can produce major changes in properties of solid polymers" [39]. All negative impact to a polymer's optical properties such as aging can affect the product's lifetime.

Interventional medicine staff use a variety of security measures against irradiation. A particularly important is to protect the eye during procedure and evaluate the explore dose during procedure. If personnel involved in the procedure required eye correction, corrective glasses for use with a protective is uncomfortable. It is possible to produce protective glasses with the right vision correction (diopter). However, the glasses can be changed by contact lenses. However, interaction of X-ray with CL induced reversible and irreversible processes in CL. Broken of polymer bond and crosslinking of polymer induced decreasing of CL transmittance. Determining of exposure dose–response curves allow to create low dose monitoring system for IR physicians.

2. EXPERIMENTAL PART

2.1. Contact lens properties

1 Day ACUVUE® MOIST a one-day lenses are made from a very soft, thin and flexible insertion materials. Made by a patented *Lacreon* ™ technology, that enables the wetting of the component retains more moisture in lens and ensures the highest comfort. These lenses are very easy to put into the eye because they have a bluish tint, and the reverse side indicator "123". They are also contact lenses protect the eyes from ultraviolet radiation.

Table 4. Hydrogel contact lenses properties used in this study.

Manufacturer	Johnson & Johnson Vistakon (USA)
Base curve	8.5
Diameter	14.2 mm.
Center thickness	0.084 mm to 0.230 mm (varies with power)
Oxygen content (DK/t)	25.5
Water content	58%
Material type	hydrogel
Material	Etafilcon A
Light transmittance	85% minimum.
Specific Gravity (calculated):	0.98 – 1.13
Refractive Index:	1.40
UV blocker	Yes

All products of ACUVUE corresponds to the second class od UV protection standard with less than 5% UVB transmittance and 50% of UVA radiation. Dependance of transmission versus light wavelength is presented in Fig.17.

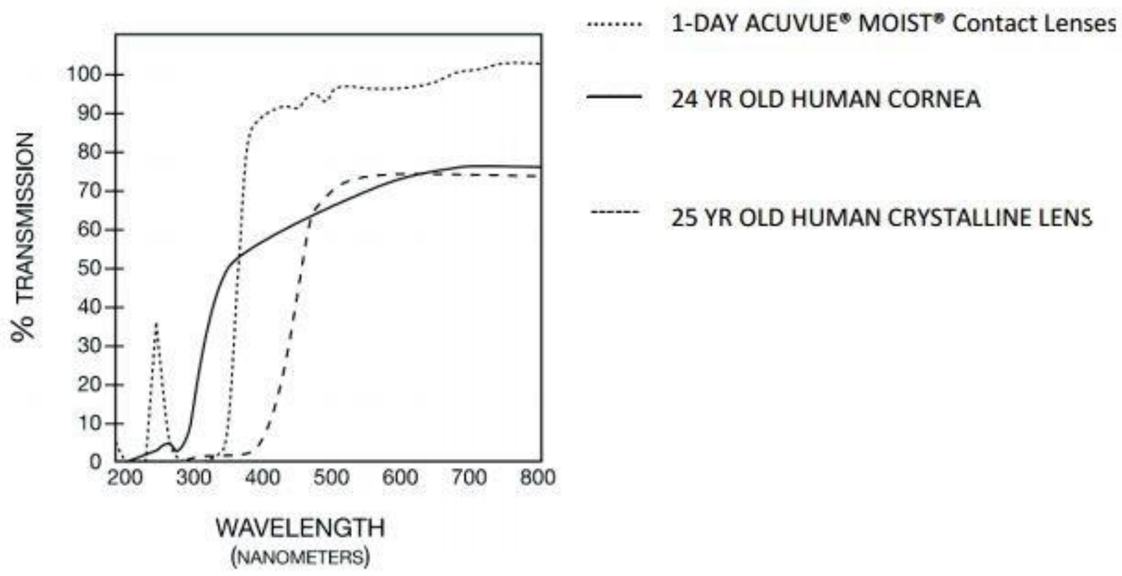

Fig.17. The data are representative measurements taken through the central 3-5 mm portion for the thinnest marketed lens (-3.00D lens, 0.084 mm center thickness) [40].

The Air Optix Aqua Multifocal contact lens with Precision Profile is designed to deliver crisp, clear vision at all distances for those with presbyopia, providing a simple transition from single vision contact lenses. All the benefits of the Air Optix Aqua material - a silicone hydrogel material claiming to provide up to 5 times greater oxygen transmissibility than traditional contact lenses. Smooth transition from close up to distance vision in real world situations.

Table 5. Silicone hydrogel „Air Optix Aqua Multifocal"contact lenses properties used in this study [41].

Manufacturer	ALCON CIBA VISION (USA)
Base curve	8.6
Diameter	14.2 mm.
Center thickness	0.08
Oxygen content (DK/t)	138
Water content	33% by weight in normal saline
Material type	Silicone hydrogel
Material	lotrafilcon B
Light transmittance	≥ 96%
Specific Gravity (calculated):	1.08

Refractive Index:	1.42
UV blocker	No

Air Optix for Astigmatism - high oxygen permeability monthly contact lenses for astigmatism correction. These monthly silicone hydrogel contact lenses are characterized by particularly good oxygen permeability, thus protects the eyes from lack of oxygen and ensures comfortable wearing. Lenses should be change every month.

Table 6. Silicone hydrogel „Air Optix for Astigmatism"contact lenses properties used in this study [41].

Manufacturer	ALCON CIBA VISION (USA)
Base curve	8.7
Diameter	14.5 mm.
Center thickness	0.102
Oxygen content (DK/t)	110
Water content	33% by weight in normal saline
Material type	Silicone hydrogel
Material	lotrafilcon B
Light transmittance	≥ 96%
Specific Gravity (calculated):	1.08
Refractive Index:	1.42
UV blocker	No

In this research was used two different materials as hydrogel and silicone hydrogel contact lenses. They as divided into three groups as shows Table 7. Choose lenses were the same diopter strength (PWR) or similar.

Table 7. Contact lenses definition and specification.

1 Day MOIST (hydrogel)	Air Optix Aqua Multifocal	Air Optix for Astigmatism
PWR		

Sph -3.0	Sph -0.25 LO (max Add +1.0)	Sph -1.50 Cyll -1.75 ax 100
Sph -3.0	Sph -0.25 LO (max Add +1.0)	Sph -1.50 Cyll -1.75 ax 20
Sph -3.0	Sph -0.50 MED (max Add +2.0)	Sph -1.50 Cyll -1.75 ax 80
Sph -3.0	Sph -0.50 MED (max Add +2.0)	Sph -1.50 Cyll -1.75 ax 70
Sph -3.0	Sph -0.50 MED (max Add +2.0)	Sph -1.50 Cyll -1.75 ax 100
Sph -3.0	Sph -0.25 LO (max Add +1.0)	Sph -1.50 Cyll -1.75 ax 70
Sph -3.0	Sph -0.50 MED (max Add +2.0)	Sph -1.50 Cyll -1.75 ax110
Sph -3.0	Sph -0.25 LO (max Add +1.0)	Sph -1.50 Cyll -1.75 ax 80
Sph -3.0	Sph -0.50 MED (max Add +2.0)	Sph -1.50 Cyll -1.75 ax100
Sph -3.0	Sph -0.25 LO (max Add +1.0)	Sph -1.50 Cyll -1.75 ax 70

2.2. UV-vis spectrometer

UV-Vis spectroscopy is used in the semiconductor industry to measure the thickness and optical properties of thin films. "If we measure the intensity of the beam of light entering our sample (Io) and compare it with the intensity of the beam of light exiting our sample (I) we can take the ratio I/Io to get an indication of what fraction of the light entering the sample was found exiting the sample" [42], [43] (Fig.18).

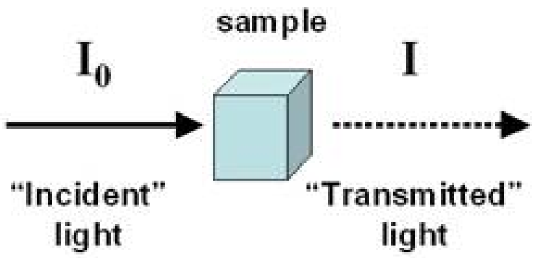

Fig.18. Placing the sample to the spectrometer [42].

This ratio is called as a transmittance as:

$$\text{Transmittance: } T = \frac{I}{I_o} \tag{1}$$

This ratio can be converted into a percentage by multiplying by 100 to get percent transmittance (%T):

$$\text{\% Transmittance: } \%T = \frac{I}{I_o} x100\% \qquad (2)$$

Absorbance (A) was found as:

$$\text{Absorbance: } A = 2 - logT. \qquad (3)$$

The method is the most often used in a quantitative way to determine concentrations of an absorbing species in solution, using the Beer-Lambert law. “The general Beer-Lambert law is usually written as:

$$A = a(\lambda) \cdot b \cdot c \qquad (4)$$

where A is the measured absorbance, a(λ) is a wavelength-dependent absorptivity coefficient, b is the path length, and c is the analyte concentration. When working in concentration units of molarity, the Beer-Lambert law is written as:

$$A = \varepsilon \cdot b \cdot c \qquad (5)$$

where ε is the wavelength-dependent molar absorptivity coefficient with units of M^{-1} cm^{-1}. Sometimes the extinction coefficient is given in other units; for example:

$$A = E^{1\%} \cdot b \cdot c \qquad (6)$$

where the concentration C is in gram per 100 ml of solution. This useful when the molecular weight of the solute is unknown or uncertain” [44]. Optical characteristics of different type contact lenses were investigated by UV-VIS spectrometer Ocean Optics USB 4000 (Fig.19).

Fig.19. Spectrometer USB4000-UV-VIS: 1. Spectometer; 2. Tungsten source;3. SR fiber. The USB4000-UV-VIS is a small spectrometer preconfigured for general UV-Vis measurements from 200-850 nm including absorption, transmission, reflectance and emission.

Spectrometer specification is given in the Table 8.

Table 8. Spectrometer UV-VIS 400 specification (45).

Engineering Specifications	**USB4000-UV-VIS**
Dimensions:	89.1 mm x 63.3 mm x 34.4 mm
Weight:	190 g
Detector:	Toshiba TCD1304AP
Wavelength range:	200-850 nm.
Integration time:	3.8 ms – 10 seconds
Signal-to-noise ratio:	300:1 (full signal)
Dynamic range:	3.4 x 10^6 (system); 1300:1 for a single acquisition
Signal-to-noise ratio:	300:1 (full signal)
Dark noise:	50 RMS counts
Grating:	600 lines/mm, set to 200-850 nm (blazed at 300 nm)
Slit:	25 µm
Detector collection lens:	No
Order-sorting:	Yes
Optical resolution:	1.5-2.3 nm FWHM
Stray light:	<0.05% at 600 nm; <0.10% at 435 nm; <10% at 250 nm
Fiber optic connector:	SMA 905 to 0.22 numerical aperture single-strand fiber

2.3. X-ray irradiation source

For contact lenses irradiation was used X-ray source that located in Hospital of Lithuanian University of Health Sciences Kauno Klinikos Oncology hospital (Volungių g. 16.). For

X-ray irradiation procedure was used “GULMAY Medical D3225” orthovoltage X-Ray therapy system (Fig.20).

Fig.20 “GULMAY Medical D3225” X-Ray therapy system.

The GULMAY Medical D3225” X-Ray therapy system output from 20kV to 210kV. During treatment procedure the dose rate is continuously monitored, preventing the dose output from deviating by more than +-3%. The unique software controlled 'ramp-up' process guarantees that the delivered dose is within 1%, even after treatment interruptions.

Contact lenses were numbered and placed, as shown in Figure 21.

Fig.21. Numeration and exposure by X-ray of CL: 1. ACUVUE 1-Day Moist, 2. The Air Optix Aqua Multifocal, 3. Air Optix for Astigmatism.

The contact lenses were irradiated with different X-ray exposure doses. The exposure parameters were selected as for typical exposure is carried out in the skin. All parameters shown in table 9.

Table 9. exposure by X-ray parameter.

Applicator number	Field size	Field coefficient	Depth	%	Voltage	Filter number	Dose	
D	20 cm	1,2096	0 cm	100	120kV	5	D (Gy)	MU
							1.0	83

All parameters were summed up panel as shown Fig.22. For the all contact lenses dose value was calculated from Gy to MU.

Fig.22. Panel view when dose value is 1Gy (83 MU).

All doses were converted from Gy to MU as shown table 10. After procedure specially for research purpose.

Table 10. Convertion of dose from Gy to MU.

CL number	Dose (Gy)	MU
1	0.1	8
2	0.2	16
3	0.3	25
4	0.4	33
5	0.5	41
6	0.6	50
7	0.7	58
8	0.8	66
9	0.9	75
10	1.0	83

2.4. Automatic lensmeter „NIDEC“ LM-1000

In every optic store are used lensmeter for check whether the glasses properly produced. Equipment, it is quite accurate for determining the eyeglass lens diopters. Lensmeter measures the spherical (sph), astigmatic (cyll, ax), prismatic (Δ) and progressive eyeglass lenses, also it is used for lens centering. LM-1000 specifications are shown in table 11.

Table 11. Automatic lensmeter „NIDEC“ LM-1000 specification (46).

Measurement Range	**LM-1000 / 1000P**
Sphere	25.0 D to +25.0 D (0.01 / 0.06 / 0.12 / 0.25 D increments)
Cylinder	0 D to ±9.99 D (-, MIX, +) (0.01 / 0.06 / 0.12 / 0.25 D increments)
Axis	0º to 180º (1º increments)
ADD	0 D to ±9.99 D (Add and Ad2) (0.01 / 0.06 / 0.12 / 0.25 D increments)
Prism	0Δ to 17Δ (horizontal), 0Δ to 20Δ (vertical), (0.01 / 0.06 / 0.12 / 0.25Δ increments)
Prism mode	Δ θ, BI/O BU/D
Measurable Lens diameter	Ø 5 to 120 mm
Measuring time	0.13 sec. (Minimum)
Measurable transmittance	10% and over (20% and over for ±15.0 D to ±25.0 D)
UV transmittance	4 levels (None, Low, Moderate, High) with 365 nm (UV-A)
Wavelength / Measuring point	660 nm (Red) / 108 within nosepiece
Marking system	Ink cartridge type (or ink pad type)
Power source	AC100 V to 120 V / 200 V to 240 V 50 / 60 Hz
Power consumption	40 VA

In this study was used lensmeter, that located in optic store at Laisvės alėja 110, Kaunas. However, using lensmeter is possible to find eyeglass lens diopter as shown figure 23. By the center of lens lens meter indicated the exact diopter: sph +0.25 -0.25 cyll ax50º.

Fig.23. Lensmeter with spectacle lens.

For this study was used tree type of contact lenses:

1. 1-Day ACUVUE Moist;
2. Air Optic Aqua Multifocal;
3. Air Optix for Astigmatism.

3. RESULTS

3.1. Lensmeter test of CL

Different type's contact lenses before irradiation were investigated by lensmeter. Difference in optical properties of contact lenses dependence on the CL materials and diopters was negligible (Fig. 24). Therefore, this method not wanting to for further research.

Fig.24. Lensmeter display data when examined contact lens.

3.2. Investigation of CL transmission before X-ray irradiation

UV-VIS spectra of different types and diopter contact lenses before X-ray irradiation are presented in Fig.25.

.

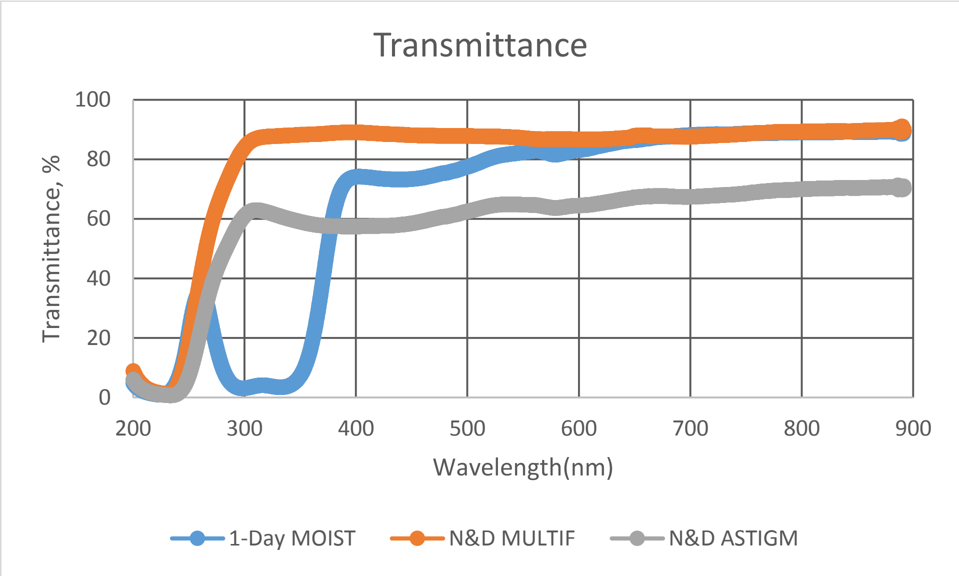

Fig.25. Different CL transmittance without exposure.

The transmittance of CL is less than 100%. T he highest transmittance has Air Optix Aqua Multifocal and 1-Day ACUVUE Moist CL. The maximum transmittance of Day ACUVUE Moist CL with UV protection is observed at 555 nm.

The same diopter of different CL transmittance is shown in Fig.26, Fig.27 and Fig.28.

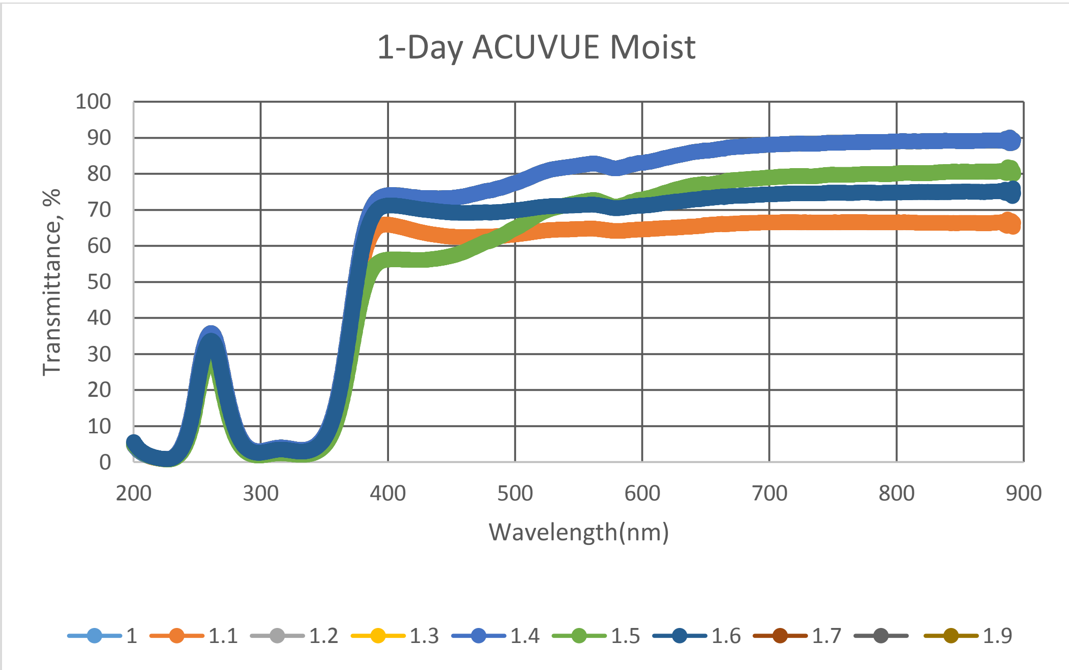

Fig.26. 1-Day ACUVUE Moist transmittance.

Transmittance varied from 60% till 90%. Due to manufacture presented information the minimum transmittance of CL reach 85%.

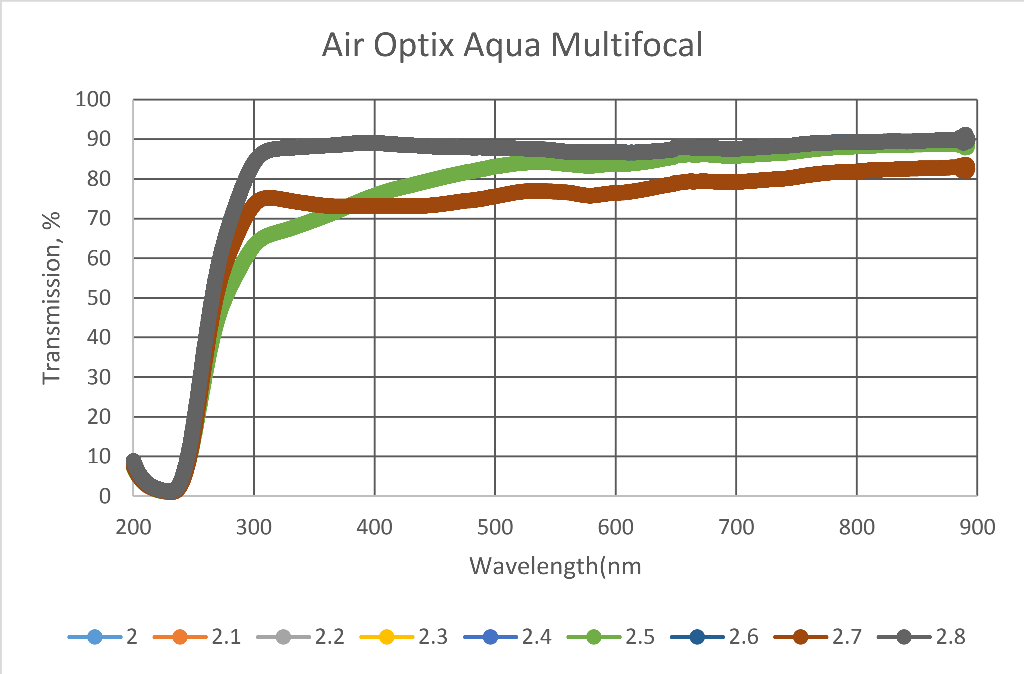

Fig.27. Air Optix Aqua Multifocal transmission.

Air Optix Aqua Multifocal transmission varied from 70% till 90%. According manufacture information transmittance of these kind of contact lenses is ≥ 96%.

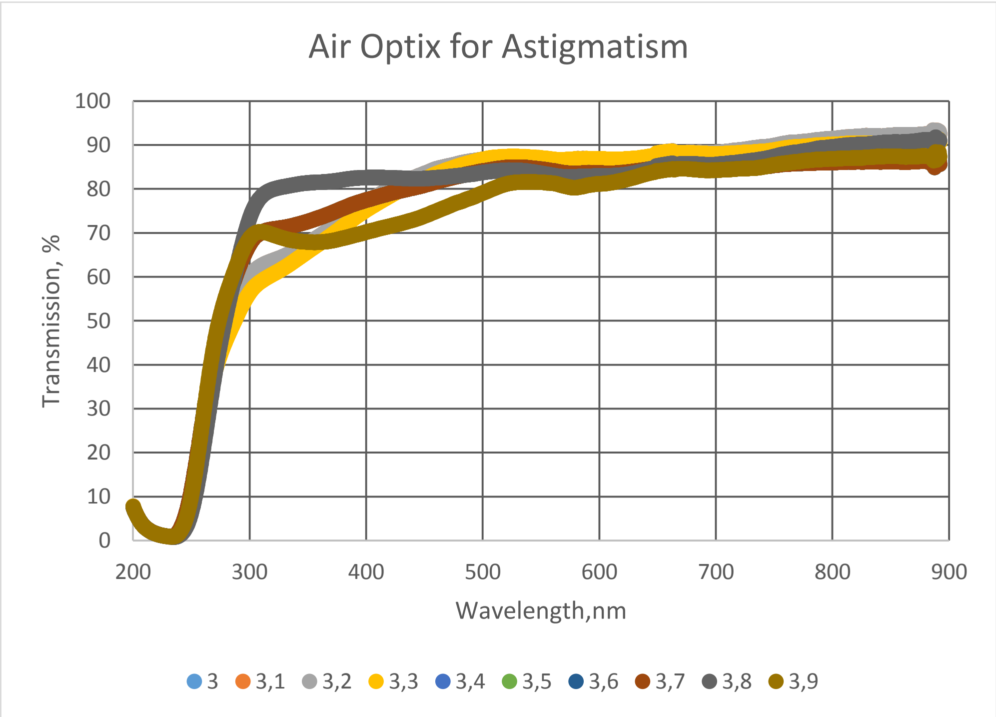

Fig.28. Air Optix for Astigmatism transmission.

Air Optix for Astigmatism CL transmittance from 70% till 90%. According manufacture information Air Optix for Astigmatism transmittance CL is ≥ 96%.

3.3. Influeance of CL solution to CL optical properties.

Different type of CL was kept in the 5% (2.775 mmol/l) glucose solution for 4 days. Normal fasting plasma glucose ranging from 3.8 to 5.5 mmol / l. If glucose concentration in the blood is from 5.6 to 7.0 mmol / l, the patient may suffer from pre-diabetes (type 1 diabetes). The discovery of more than 7.0 mmol / l means a person is likely to have type 2 diabetes. To verify that the lens storage conditions have influence on the light permeability, one lens of each group were placing in the glucose solution (5%) for four days. As shown Fig.29 some CL light transmittance are lowest than considered in physiological solution.

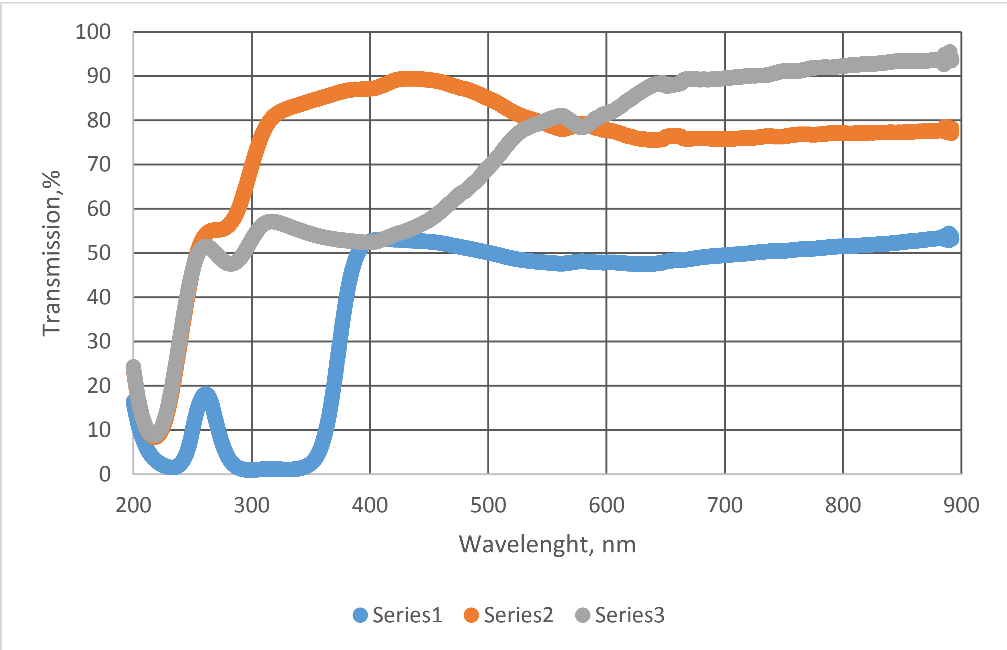

Fig.29. CL transmission after 4 days in a 5% glucose solution: series 1 – 1-Day ACUVUE Moist, series 2 - Air Optix Aqua Multifocal, series 3 - Air Optix for Astigmatism.

Transmittance of 1-Day ACUVUE Moist before glucose solution varied from 60% till 90%, after that decrease up to ±50%. Air Optix Aqua Multifocal CL transmittance were from 70% till 90% before glucose solution and it stayed similar. Air Optix for Astigmatism transmittance also changed from 70% till 90% and after glucose solution distributed unevenly: at the wavelength region 253nm - 624nm transmittance increased unevenly (from 50% to 85%), but up 624nm it is about 70%-80%.

In this case we can say that the glucose solution affects lens light permeability. The biggest influence is visible lenses made of *Etafilcon A* - throughput decreased about 35%. The reason can be that the CL material are sensitive to glucose solution and often reduced crusty what gives light transmission loss. This is the way to explain why the results of CL can be influence dose measurement results. If a person has a large amount of sugar in tears they could be influence the dose measurement result also.

3.4. UV-VIS spectra of CL after X-ray irradiation

Irradiated by X-ray CL were investigated by UV-VIS spectrometer. The UV-Vis spectra of these CL are presented in Fig. 30, Fig. 31 and Fig. 32.

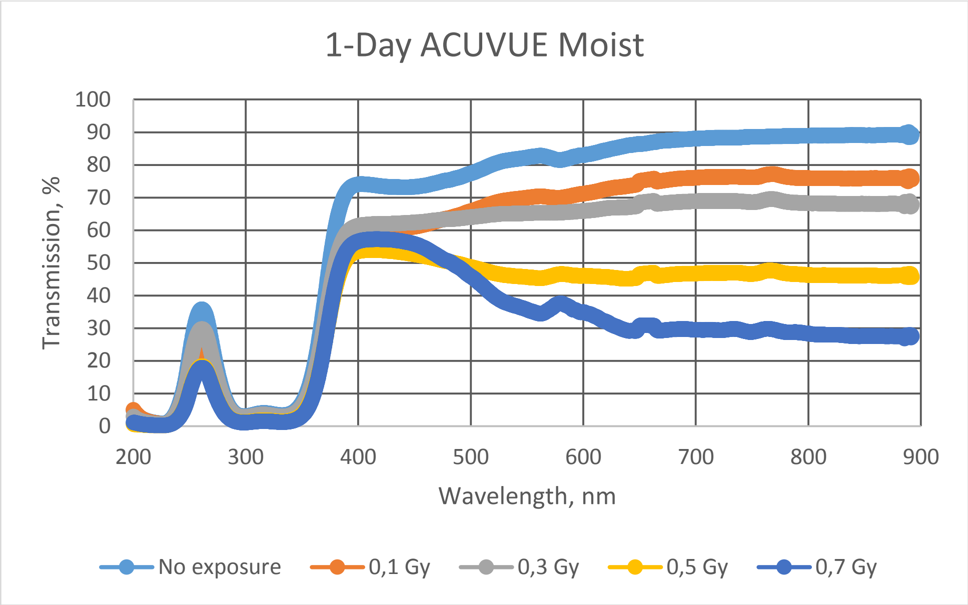

Fig.30. UV-VIS spectra of 1-Day ACUVUE Moist CL

.

However, the X-ray irradiation induced in in reversible changes CL (1-Day ACUVUE Moist) polymer structure, that observed as decreasing of transmittance in UV-VIS spectra. By comparing UV-VIS spectra of the same contact lenses before and after irradiation, it was found that transmittance of CL (1-Day ACUVUE Moist) after expose by X-ray irradiation (0.7 Gy) decreased up to 30%-40%.

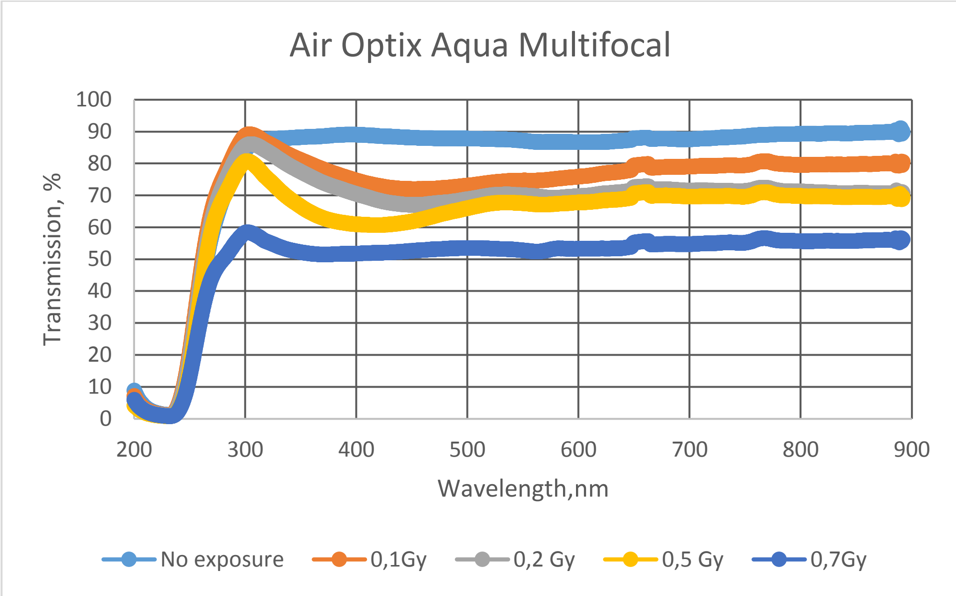

Fig.31. UV-VIS spectra of Air Optix Aqua Multifocal.

It was found also that expose dose is affected transmittance of Air Optix Aqua Multifocal in the width region of optical stectra. Comparing CL with no exposure and CL after 0.7 Gy exposure, light transmittance decreased about 40%.

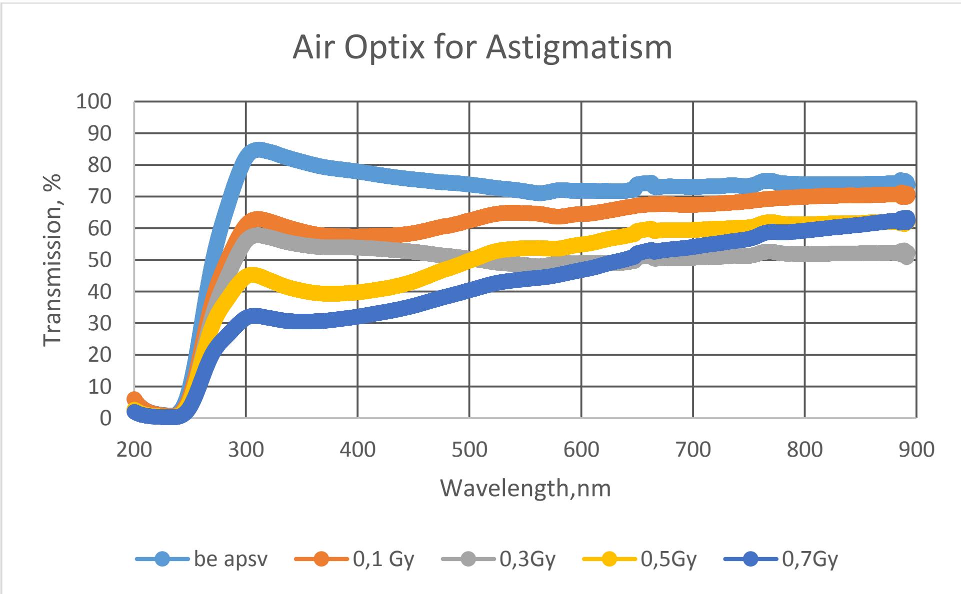

Fig.32. UV-VIS spectra of Air Optix for Astigmatism

Transmittance spectra of Air Optix for Astigmatism CL is presented in Fig.32. Transmittance of CL decreasing by exposed dose. By comparing UV-VIS spectra of CL without and after X-ray exposure and CL after 0.7 Gy exposure, light transmittance decreased up to 50% at the first vertex (when wavelength is about 300nm). At other wavelengths schedule is distributed unevenly: at different irradiation of CL, transmission curves fall and rise disproportionately.

3.5. Optical density difference

It is well known, that the human eye spectral sensitivity for different areas of the visible spectrum is variable, depending on the wavelength. Solar power has the largest spectrum of yellow-green radiation. Eyes sensitive to waves of a wavelength λ = 555 nm. Visual sensitivity of this treated as a single color (J = 1). Eye sensitivity to other colors of the color seen relatively concerned. Both the wavelength λ decreases toward the purple wavelength λV and increasing toward the red λR visual sensitivity decreases. For these reason was selected tree tops charts:

1. 232,05nm (UVC) (germicidal laps used in operational sterilization);
2. 333,16 nm (UVA) (does not inhibit the optical glasses);
3. 554,96 nm (most sensitive to human eyes);
4. 660,02 nm (used in lensmeter).

UVA radiation is absorbed by the cornea and retina. UVB rays are absorbed by the lens of the eye and part of the retina.

For each type of lenses were studied absorbance dependence on the dose. 1-Day ACUVUE Moist lenses was irradiated by tree dose values: 0.1Gy,0.2 Gy, 0.5 Gy, 0.7 Gy and 0.8 Gy. Each contact lens dose depedance curves described by the second order - polynomials, as shown Figure 33, Figure 34, Figure 35 and Figure 36.

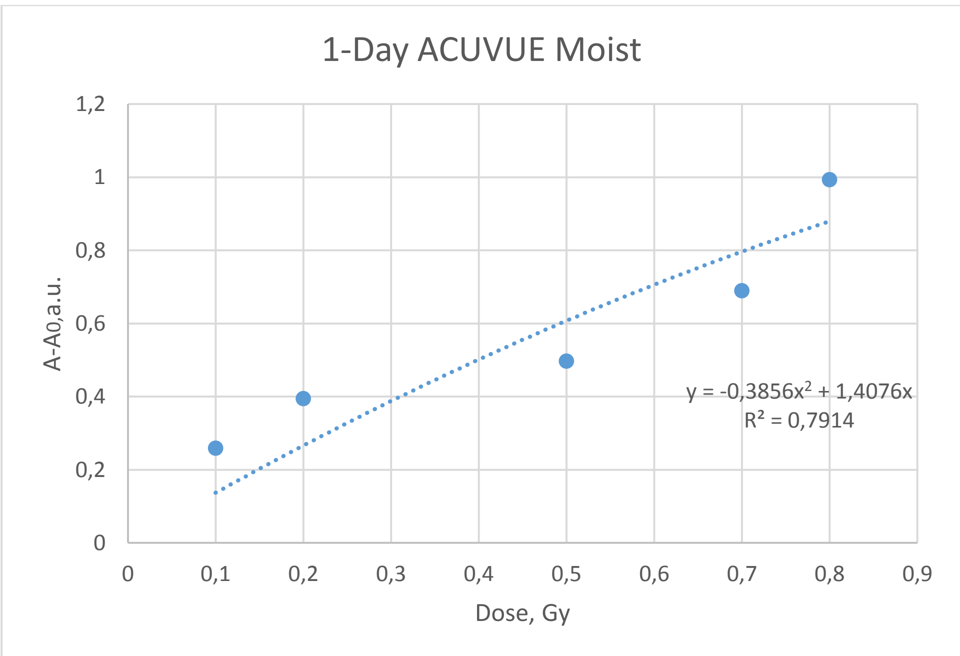

Fig.33. Dose dependence curve 232.05 nm wavelength.

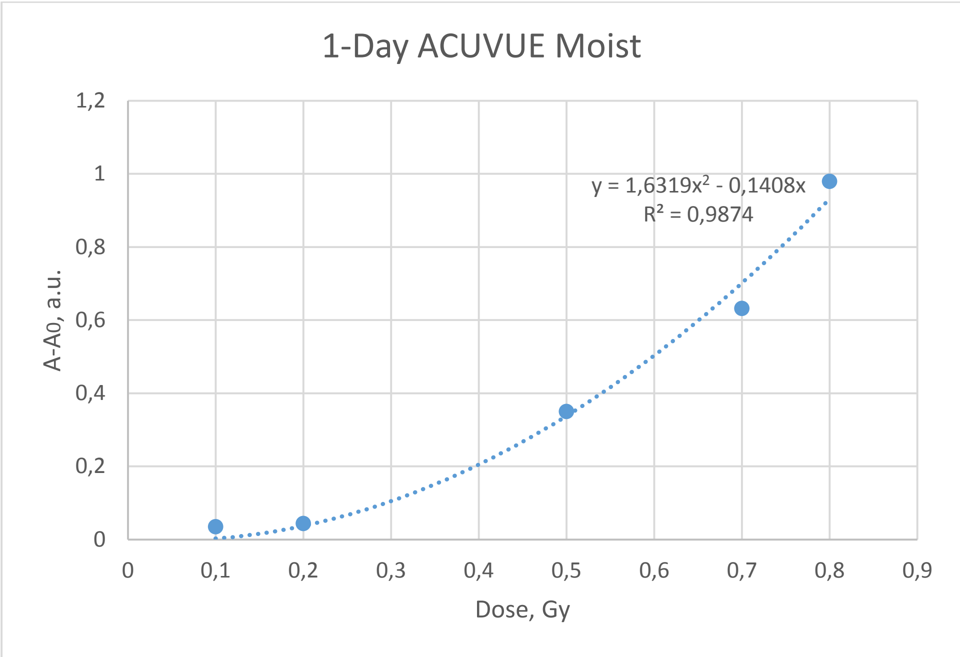

Fig.34. Dose dependence curve 333.16 nm wavelength..

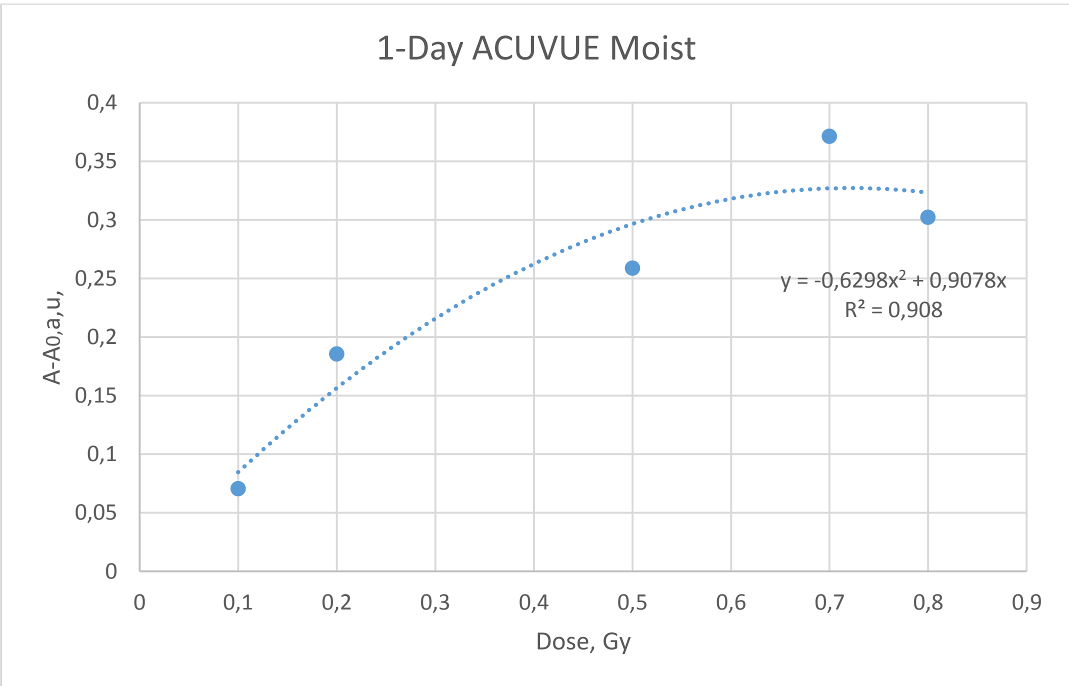

Fig.35. Dose dependence curve 554.96 nm wavelength.

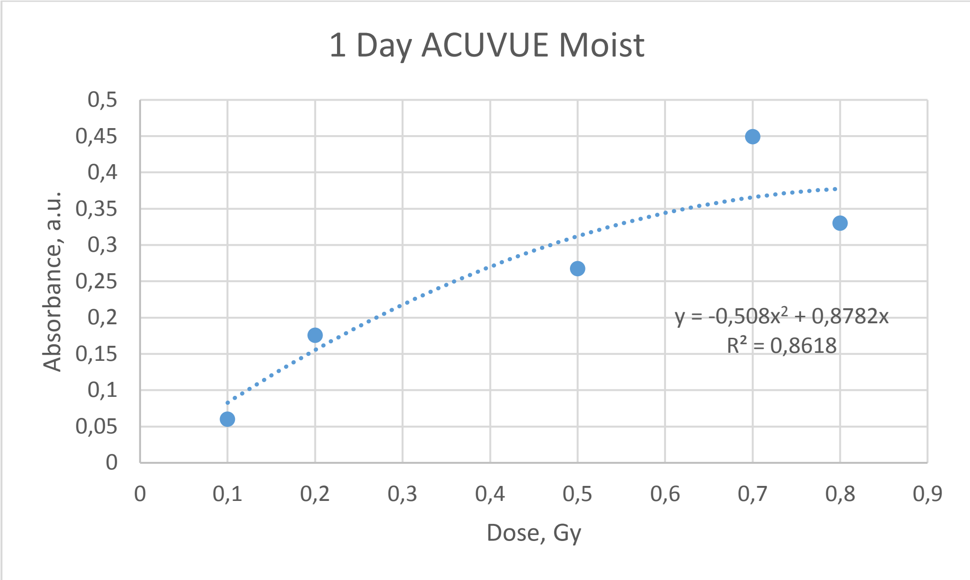

Fig.36. Dose dependence curve 660,02 nm wavelength.

Summarized dose dependence curve approximation results are presented in Table 12.

Tab.12. Dose dependence curves analysis results.

Wavelength (nm)	Lenses	Material	Equation
232.05	1-Day ACUVUE Moist	Etafilcon A	$y = -0.3856x^2 + 1.4076x$ $R^2 = 0.7914$
333.16	1-Day ACUVUE Moist	Etafilcon A	$y = 1.6319x^2 - 0.1408x$ $R^2 = 0.9874$
554.96	1-Day ACUVUE Moist	Etafilcon A	$y = -0.6298x^2 + 0.9078x$ $R^2 = 0.908$
660.02	1-Day ACUVUE Moist	Etafilcon A	$y = -0.508x^2 + 0.8782x$ $R^2 = 0.8618$

Air Optix Aqua Multifocal contact lenses was irradiated by four dose values: 0.1 Gy 0.3Gy, 0.4 Gy, 0.6 Gy and 0.8 Gy. Each contact lens dose dependency curves on wavelength shown Figure 37, Figure 38, Figure 39 and Figure 40.

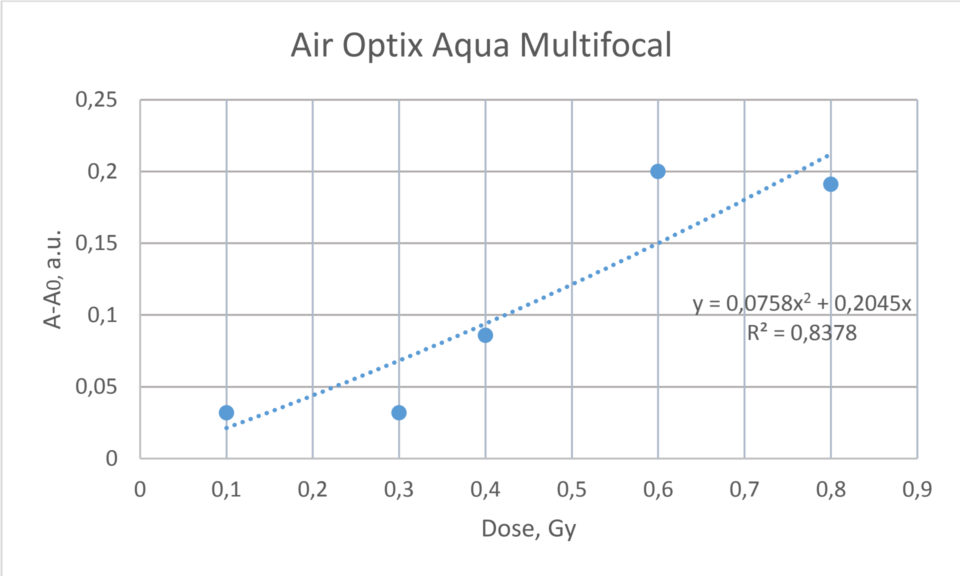

Fig.37. Dose dependence curve at wavelength 232.05 nm.

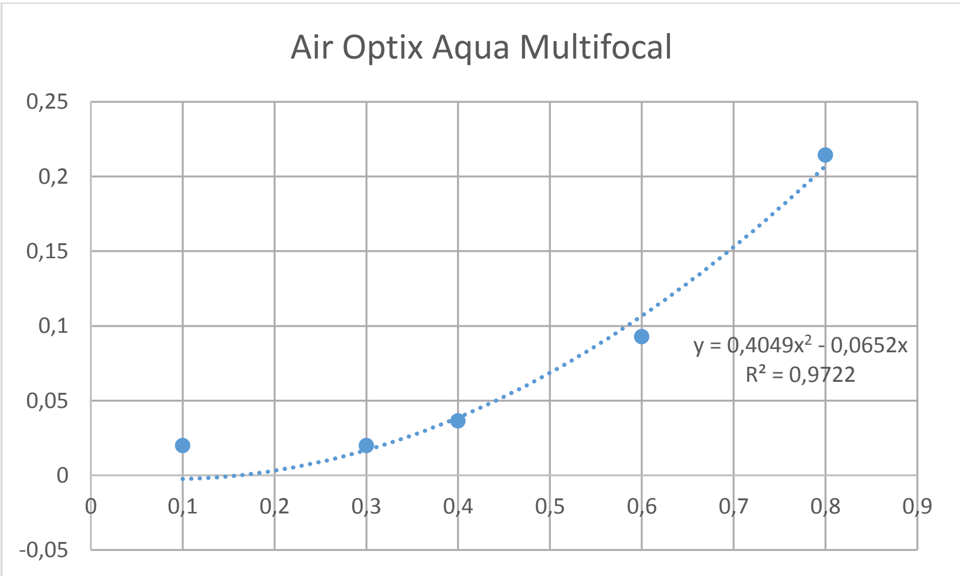

Fig.38. Dose dependence curve at wavelength 333.16 nm.

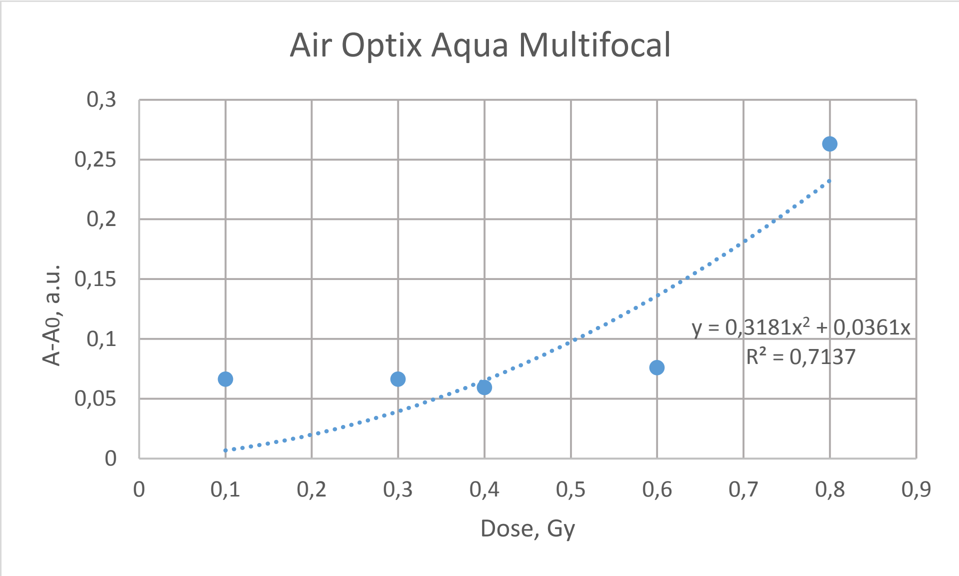

Fig.39. Dose dependence curve at wavelength 554.96 nm.

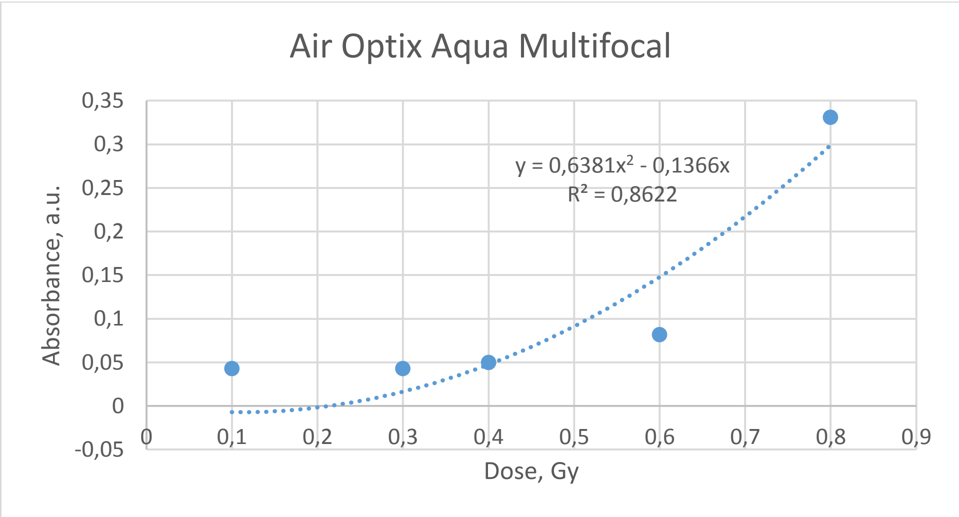

Fig.40. Dose dependence curve at wavelength 660.02 nm.

Summarized dose dependence curve approximation by the second order polynomic equation are presented in. The graphs were analyzed and was obtained functions that describe a polynomial curve as shown Table 13.

Tab.13. Dose dependence curves analysis results.

Wavelength (nm)	Lenses	Material	Equation
232.05	Air Optix Aqua Multifocal	Lotrafilcon B	$y = 0.0758x^2 + 0.2045x$ $R^2 = 0.8378$

333.16	Air Optix Aqua Multifocal	Lotrafilcon B	$y = 0.4049x^2 – 0.0652x$ $R^2 = 0.9722$
554.96	Air Optix Aqua Multifocal	Lotrafilcon B	$y = 0.3181x^2 + 0.0361x$ $R^2 = 0.7137$
660.02	Air Optix Aqua Multifocal	Lotrafilcon B	$y = 0.6381x^2 – 0.1366x$ $R^2 = 0.8622$

Air Optix forAstigmatism contact lenses was irradiated by tree exposure dose values: 0.1Gy, 0.3 Gy, 0.5 Gy, 0.7 Gy and 1.0 Gy. Each contact lens dose dependence were approximated by the second order polynomic curve as shown Figure 41, Figure 42, Figure 43 and Figure 44.

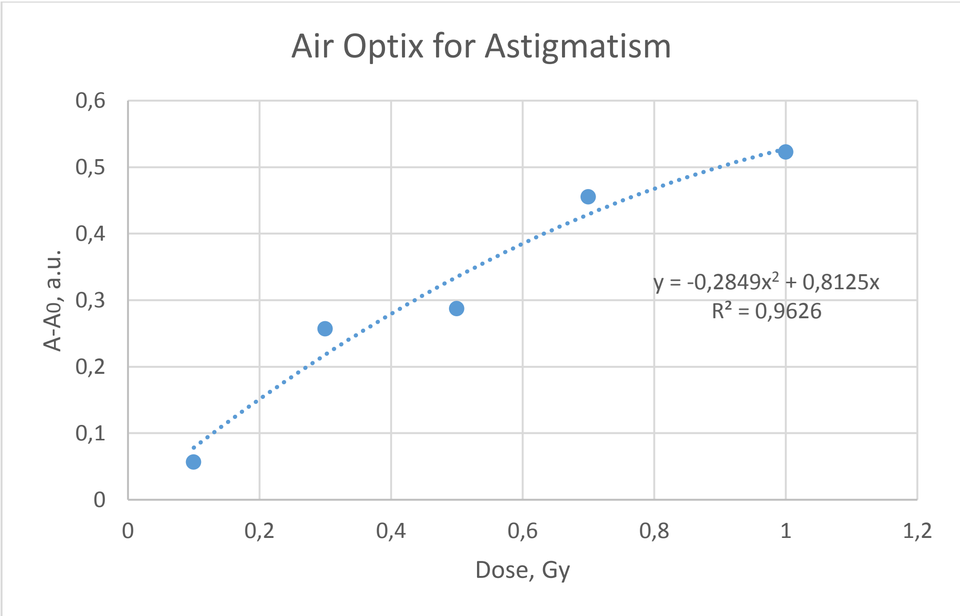

Fig.41.Dose dependence curve at 232.05 nm wavelength.

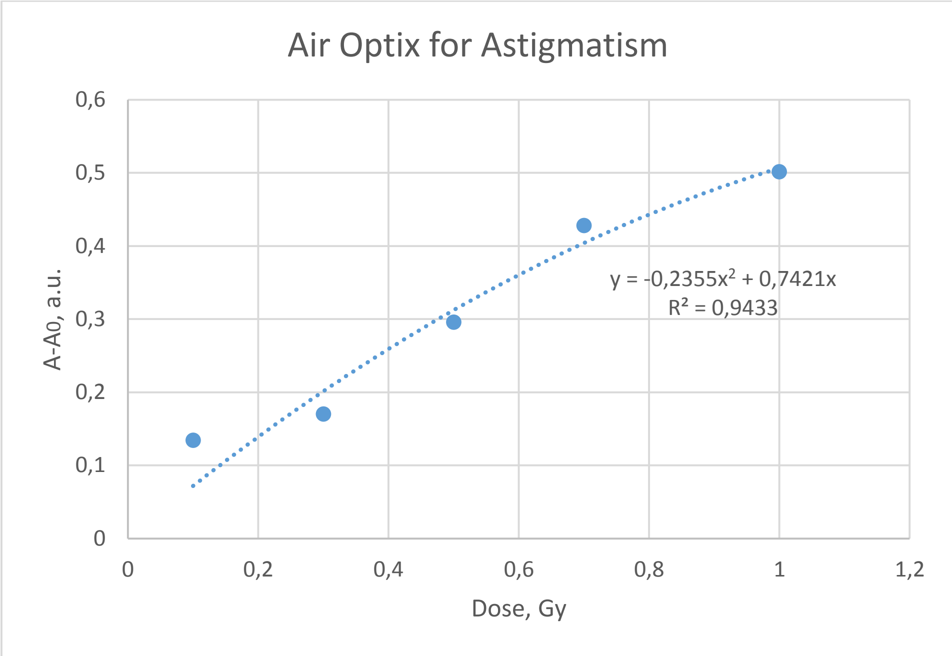

Fig.42. Dose dependence curve for wavelength 333.16 nm.

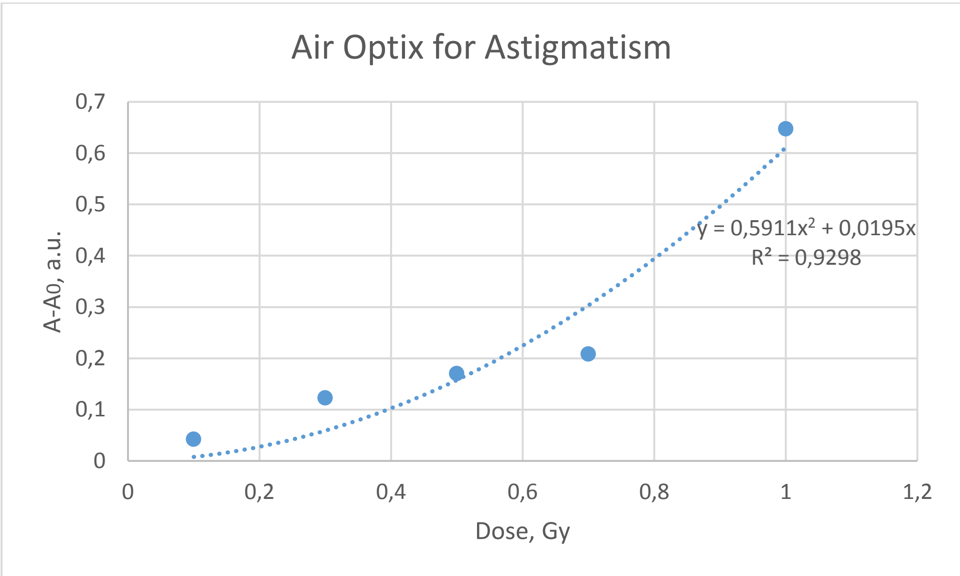

Fig.43.Dose dependence curve for wavelength 554.96 nm

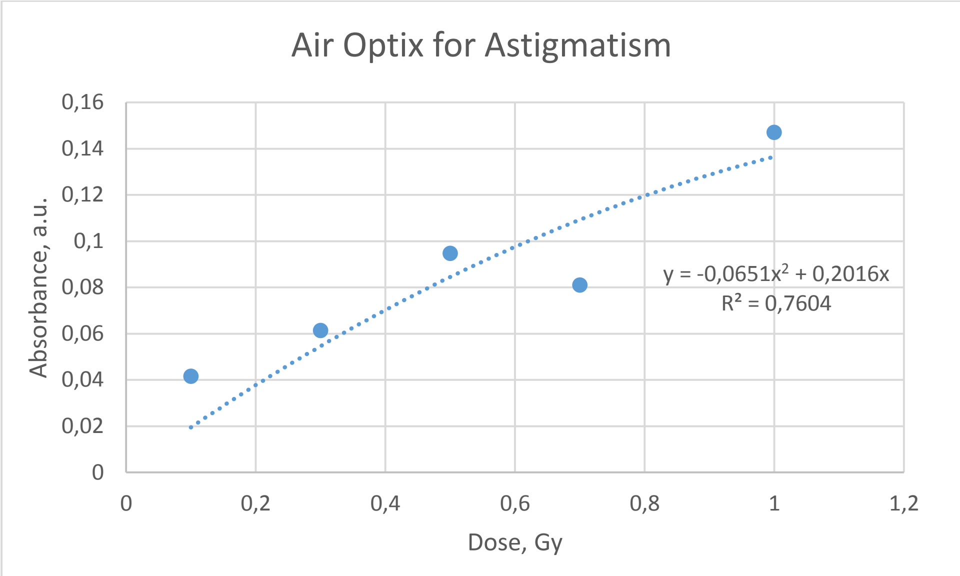

Fig.44. Dose dependence curve at wavelength 660.02 nm

The graphs were analyzed and was obtained functions that describe a polynomial curve as shown table 14.

Tab.14. Summarised dose dependence curves approximation results.

Wavelength (nm)	Lenses	Material	Equation
232.05	Air Optix for Astigmatism	Lotrafilcon B	$y = -0.2849x^2 + 0.8125x$ $R^2 = 0.9626$
333.16	Air Optix for Astigmatism	Lotrafilcon B	$y = -0.2355x^2 + 0.7421x$ $R^2 = 0.9433$
554.96	Air Optix for Astigmatism	Lotrafilcon B	$y = 0.5911x^2 + 0.0195x$ $R^2 = 0.9298$
660.02	Air Optix for Astigmatism	Lotrafilcon B	$y = -0.0651x^2 + 0.2016x$ $R^2 = 0.7604$

4.6. Evaluation of exposure dose using CL dose dependence curves

The CL dose dependence curve, that was found in the previous chapter, were apply to determinate the exposed dose of irradiated by X-ray CL. Irradiated by unknown expose dose contact lenses were investigated by UV-VIS spectrometer. Absorbance difference of irradiated and non-irradiated lens was calculated using UV-VIS spectra (Table 15). Was calculated optical density difference for each wavelength as shown table 15.

Tab.15. Absorbance difference for different CL at the different wavelength.

Lens	Lens number	A-Ao			
		232.05 nm	333.16 nm	554.96 nm	660.02 nm
1-Day ACUVUE Moist	01	0.32	0.797	0.085	0.060
1-Day ACUVUE Moist	02	1.309	2.987	0.101	0.175
1-Day ACUVUE Moist	03	1.163	2.84	0.480	0.101
1-Day ACUVUE Moist	04	0.951	2.215	0.185	0.042
1-Day ACUVUE Moist	05	0.498	1.265	0.371	0.267
1-Day ACUVUE Moist	06	0.886	1.818	0.61	0.189
1-Day ACUVUE Moist	07	0.931	1.489	0.61	0.449
Air Optix Aqua Multifocal	08	0.0425	0.1342	0.0425	0.0429
Air Optix Aqua Multifocal	09	0.0663	0.1658	0.066	0.1378
Air Optix Aqua Multifocal	10	0.123	0.1702	0.123	0.0429
Air Optix Aqua Multifocal	11	0.0571	0.1703	0.0571	0.0499
Air Optix Aqua Multifocal	12	0.1707	0.0599	0.1707	0.0938
Air Optix for Astigmatism	13	0.0569	0.1342	0.0425	0.0577
Air Optix for Astigmatism	14	0.2593	0.1658	0.0663	0.0613

Air Optix for Astigmatism	15	0.2574	0.1702	0.1231	0.0612
Air Optix for Astigmatism	16	0.1464	0.1703	0.0571	0.0946
Air Optix for Astigmatism	17	0.2873	0.2958	0.1707	0.2239
Air Optix for Astigmatism	18	0.2873	0.2958	0.1231	0.0810
Air Optix for Astigmatism	19	0.4557	0.4279	0.2087	0.2006

According to equation of the dose dependence curve the estimated expose dose of the each lens was calculated and it shown in Table 16.

Tab.16. Dose values calculated from calibration curve.

Lens	Lens number	A-Ao				Calculated dose (Gy)			
		232.05 nm	333.16 nm	554.96 nm	660.02 nm	232.05 nm	333.16 nm	554.96 nm	660.02 nm
1-Day ACUVUE Moist	01	0.32	0.797	0.085	0.060	0.92	3.60	0.10	0.12
1-Day ACUVUE Moist	02	1.309	2.987	0.101	0.175	0.41	0.92	0.12	0.34
1-Day ACUVUE Moist	03	1.163	2.84	0.480	0.101	1.18	14.13	0.15	0.20
1-Day ACUVUE Moist	04	0.951	2.215	0.185	0.042	1.11	12.76	1.16	0.08
1-Day ACUVUE Moist	05	0.498	1.265	0.371	0.267	0.60	3.48	0.49	0.50

1-Day ACUVUE Moist	06	0.886	1.818	0.61	0.189	0.98	7.69	0.32	0.36
1-Day ACUVUE Moist	07	0.0425	1,489	0.61	0.449	0.60	2.43	0.80	0.78
Air Optix Aqua Multifocal	08	0.0425	0.1342	0.0425	0.0429	0.05	0.17	0.001	0.29
Air Optix Aqua Multifocl	09	0.0663	0.1658	0.066	0.1378	0.15	0.22	0.003	0.75
Air Optix Aqua Multifocal	10	0.123	0.1702	0.123	0.0429	0.16	0.23	0.011	0.29
Air Optix Aqua Multifocal	11	0.0571	0.1703	0.0571	0.0499	0.11	0.23	0.003	0.34
Air Optix Aqua Multifocal	12	0.1707	0.2958.	0.1707	0.0938	0.16	0.46	0.020	0.57
Air Optix for Astigmatism	13	0.0569	0.1342	0.0425	0.0414	0.05	0.17	0.001	0.22
Air Optix for Astigmatism	14	0.2593	0.1658	0.0663	0.0577	0.15	0.22	0.003	0.32
Air Optix for Astigmatism	15	0.2574	0.1702	0.1231	0.0613	0.16	0.23	0.011	0.34
Air Optix for Astigmatism	16	0.1464	0.1703	0.0571	0.0612	0.11	0.23	0.003	0.34
Air Optix for Astigmatism	17	0.2873	0.2958	0.1707	0.0946	0.16	0.46	0.020	0.58

Air Optix for Astigmatism	18	0.2873	0.2958	0.1231	0.2239	0.16	0.46	0.011	1.80
Air Optix for Astigmatism	19	0.4557	0.4279	0.2087	0.1707	0.13	0.76	0.029	0.48

CONCLUSIONS

1. For 1-Day ACUVUE Moist contact lenses transmission is lower about 20% comparing between Optix Aqua Multifocal and Air Optix.
2. The changes in the characteristics of optical lenses is also affected by storage conditions. The biggest influence is visible lenses made of *Etafilcon A* - throughput decreased about 35%.
3. X-ray irradiation change contact lenses optical properties. Contact lens transmittance after 0,7 Gy exposure decreased about 40%.
4. Dose response curve of contact lenses was used for dose estimation. The graphs were analyzed and was obtained functions that describe a polynomial curve for each contact lens.

REFERENCES

1. Jerrold T.Bushberg, J.Anthony Seibert, Edwin M. Leidholdt, JR., John M. Boone. *The essential physics of medical imaging.* USA: Lippincott Williams & Wilkins, 2002.
2. The Home of Image Guided Surgery. *What is Interventional Radiology?* [interactive]. 2013 [previewed 2017-02-04]. Access through internet: http://www.bsir.org/patients/what-is-interventional-radiology/
3. Kardiolitos klinika. *Intervencinė radiologija* [interactive]. 2016 [previewed 2017-02-04]. Access through internet: http://www.kardiolita.lt/lt/intervencine-radiologija
4. John Hopkins Medicine. *Vascular and Interventional Radiology* [interactive]. [previewed 2017-02-04]. Access through internet: http://www.hopkinsmedicine.org/interventional-radiology/procedures/pta/
5. The free dictionary by Farlex. *Percutaneous transluminal angioplasty* [interactive]. [previewed 2017-02-04]. Access through internet: http://medical-dictionary.thefreedictionary.com/percutaneous+transluminal+angioplasty
6. RadiologyInfo.org For patients. *Catheter Embolization* [interactive]. 2016 [previewed 2017-02-05]. Access through internet: https://www.radiologyinfo.org/en/info.cfm?pg=cathembol
7. Maurice Balke, Marcel P. Henrichs, Georg Gosheger, Helmut Ahrens, Arne Streitbuerger, Michael Koehler, Viola Bullmann and Jendrik Hardes. Giant Cell Tumors of the Axial Skeleton. *Clinical Study* [interactive]. Hindawi Publishing Corporation 2012, 6-7 [previewed 2017-02-05]. Access via ResearchGate: https://www.researchgate.net/publication/221976816
8. Daniel A. Siragusa, MD, John F. Cardella, MD, Robert A. Hieb, MD, John A. Kaufman, MD, MS, Hyun S. Kim, MD, Boris Nikolic, MD, MBA, Sanjay Misra, MD, Scott A. Resnick, MD, Wael E. Saad, MD, Geogy Vatakencherry, MD, and Michael J. Wallace, MD. Requirements for Training in Interventional Radiology. *Standart of practice.* [interactive] 2013, 1609–1612, Access via doi: http://dx.doi.org/10.1016/j.jvir.2013.08.002
9. IRPA. IRPA guideline protocol for eye dose monitoring and eye protection of workers [interactive]. [previewed 2017-02-07]. Access through internet: http://www.irpa.net/members/54696/%7B922B536A2F1D468B9A9E61655828DBE6%7D/IRPA%20guideline%20protocol%20for%20eye%20dose%20monitoring%20%20and%20eye%20protection%20of%20workers.pdf

10. Eleftheria Carinou1, Paolo Ferrari, Olivera Ciraj Bjelac, Merce Gingaume, Marta Sans Merce and Una O'Connor. Eye lens monitoring for interventional radiology personnel: dosemeters, calibration and practical aspects of H p (3) monitoring. A 2015 review. *Society for Radiological Protection* [interactive] 2015, 35, 23-24. Access via doi: http://dx.doi.org/10.1088/0952-4746/35/3/R17
11. RadPro International GmbH. Your provider for TLD and OSL systems [interactive]. [previewed 2017-02-08]. Access through internet: https://www.radpro-int.com/tld-1/dosimeter/
12. Public Health England. Eye dosemeters [interactive]. [previewed 2017-02-08]. Access through internet: https://www.pheprotectionservices.org.uk/cms/assets/gfx/content/resource_2974cs6788076842.pdf
13. Martin CJ, Magee, JS. Assessment of eye and body dose for interventional radiologists, cardiologists, and other interventional staff. *J. Radiological Protection* [interactive]. 2013, 33, 445-460. Access via doi: http://dx.doi.org/10.1088/0952-4746/33/2/445
14. Radiation Safety. CLEAR-Pb® Shielding and Mobile Barriers [interactive]. 2003 [previewed 2017-02-10]. Access through internet: http://www.elimpex.com/companies/victoreen/Catalog/RS6.pdf
15. Wardray premise. X-ray Protective Mobile Screens and Workstations [interactive]. 2005-2015 [previewed 2017-02-10]. Access through internet: http://www.wardray-premise.com/xray/personnel/screens.html#panoramic
16. Philips Safety Productions. Radiation Eyewear [interactive]. 2016 [previewed 2017-02-10]. Access through internet: http://www.phillips-safety.com/radiation-protection/radiation-eyewear.html
17. Dr. S.M.S. Raza (UK). Radiation exposure in the cath lab – safety and precautions [interavtive]. 2006 [previewed 2017-02-12]. Access through internet: http://www.priory.com/med/radiation.htm
18. L. Struelens & S. Krim F. Vanhavere. Extremity Doses of Medical Staff for Complex Interventional Procedures and in Nuclear Medicine ExDos. *Final report* [interactive]. 2010 [previewed 2017-02-12]. Access through internet: http://fanc.fgov.be/GED/00000000/2700/2757.pdf
19. ICRP 2013: 2nd International Symposium on the System of Radiological Protection. Dose limits to the lens of the eyes: New limit for the lens of the eye - International Basic Safety

Standards and related guidance [interactive]. 2013 [previewed 2017-02-15]. Access through internet:
http://www.icrp.org/docs/Miroslav%20Pinak%20Dose%20Limits%20to%20the%20Lens%20of%20the%20Eyes%20New%20Limit%20for%20the%20Lens%20of%20the%20Eye%20%20International%20Basic%20Safety%20Standards%20and%20Related%20Guidance.pdf

20. O.A Olufayo, K. Abou-El-Hossein, M.M Kadernani. Tribo-electric Charging in the Ultra-high Precision Machining of Contact lens Polymers. *Procedia Materials Science* [interactive]. South-Africa: Port-Elizabeth 2014, 6, 195–196. [previewed 2017-02-16]. Available at Science Direct:
http://www.sciencedirect.com/science/article/pii/S2211812814003897
21. Nick Siviglia, Sc.D., Ph.D. History of contact lenses [interactive]. 2010 [previewed 2017-02-17]. Access through internet:
http://edwardhandmedicalheritage.org/images/History_of_Contact_Lenses.pdf
22. Improve sight HQ. Different type of contact lenses and how they work [interactive]. 2012-2017 [previewed 2017-02-17]. Access through internet:
http://www.improveeyesighthq.com/type-of-contact-lens.html
23. Alastair Selbya, Carole Maldonado-Codinab, Brian Derbya. Influence of specimen thickness on the nanoindentation of hydrogels: Measuring the mechanical properties of soft contact lenses. *Research Paper* [interactive]. 2013, 35, 144-145, [previewed 2017-02-16]. Available at Science Direct:
http://www.sciencedirect.com/science/article/pii/S1751616113004116
24. Barry A. Weissman, O.D., Ph.D., Joseph T. Barr, O.D., Michael G. Harris, O.D., J.D. and other. *Optometric clinical practice guideline care of the contact lens patient 2nd edition*. Reference Guide for Clinicians. USA: N. Lindbergh Blvd., St. Louis,2006, 5-6. MO 63141-7881.
25. Yasuo Matsuzawa & Jurgen Vogt. Silicone Hydrogels As Continous & Extended Wear Contact Lens Material [interactive]. [Previewed 2017-02-18]. Access through internet:
http://www.issp.utokyo.ac.jp/public/GelSympo2003/Proceedings/digitalproceedings/pdf_files/II_15Matsuzawa2.pdf
26. Yu Jin Cho, Jun-Pil Jee. Hydrogel lenses functionalized with surface-immobilized PEG layers for reduction of protein adsorption. *Pharmaceutical sciences* [interactive]. 2016, 148–149. [previewed 2017-02-20]. Available at Science Direct:
http://www.sciencedirect.com/science/article/pii/S1818087615002457

27. Sveikatos ABC. *Kontaktiniai lęšiai ir akių sveikata* [interactive]. 2008, 2, 16-17, [previewed 2017-02-10]. Access through internet: http://www.sveikatosabc.lt/pdf/2008/abc2008_02.pdf
28. All About Vision. *Contact Lenses for Astigmatism: Toric, GP and Hybrid Lenses* [interactive]. 2016 [previewed 2017-02-22]. Access through internet: http://www.allaboutvision.com/contacts/torics.htm
29. Anna Sulleya, Ryan Hawkeb, Kathrine Osborn Lorenzc, Youssef Touboutic, Giovanna Olivaresc. Resultant vertical prism in toric soft contact lenses [interactive]. 2015, 38(4), 253–257, [previewed 2017-02-22]. Available at Science Direct: http://www.sciencedirect.com/science/article/pii/S1367048415000375
30. My Alcon: *A Guide to Clinical Contact Lens Management* [interactive]. 2014 [previewed 2017-02-25]. Access through internet: https://www.myalcon.com/education/academy-eye-care-excellence/cclm/soft-toric-lens-mislocation.shtml
31. All About Vision: *Bifocal and Multifocal Contact Lenses* [interactive]. 2016 [previewed 2017-02-22]. Access through internet: http://www.allaboutvision.com/contacts/bifocals.htm
32. Encyclopeadia Britannica: *Surfactant.Chemical Compound* [interactive]. 2017 [previewed 2017-03-10]. Access through internet: https://www.britannica.com/science/surfactant
33. Jean-Louis Salager. *Surfactants. Types and Uses* [interactive]. 2002 (2) [previewed 2017-03-12]. Access through internet: http://www.nanoparticles.org/pdf/Salager-E300A.pdf
34. Hair Information and Advice, with a pinch of Science. *Types of surfactants in your shampoo* [interactive]. 2016 [previewed 2017-03-12]. Access through internet: http://hairmomentum.com/types-of-surfactants-in-shampoo/
35. Anthony J. O'Lenick, Jr. *Surfactants: Strategic Personal Care Ingredients.* USA: Allured Publishing Corporation, 2014. ISBN 978-1-932633-96-2
36. Richard J. Farn. *Chemistry and Technology of Surfactants*. UK: Blackwell Publishing Ltd,2006, ISBN-13: 978-14051-2696-0
37. G. Nelson and D. ReWy. *Gamma-Ray Interactions with Matter* [interactive]. [previewed 2017-04-10]. Access through internet: http://www.lanl.gov/orgs/n/n1/panda/00326397.pdf
38. Daniel R. McAlister, Ph.D. *Gamma Ray Attenuation Properties of Common Shielding Materials* [interactive]. 2013 [previewed 2017-04-10]. Access through internet:

http://www.eichrom.com/PDF/gamma-ray-attenuation-white-paper-by-d.m.-rev-4.pdf

39. Eman Kamal Mohammed Tawfik. *Radiation effect on characterization and physical properties of polymer nanocomposites* [interactive]. 2013 2015 [previewed 2017-04-14]. Access through internet:
http://www.iaea.org/inis/collection/NCLCollectionStore/_Public/46/066/46066329.pdf
40. Acuvue: *1-DAY ACUVUE® MOIST® Brand Contact Lenses* [interactive]. 2015 [previewed 2017-03-10]. Access through internet:
https://www.acuvue.com/sites/acuvue_us/files/m-09-14-00_1davm_pi-fig_website.pdf
41. Ciba Vision: *O_2OPTIX®, AIR OPTIX® AQUA, AIR OPTIX® for ASTIGMATISM, and AIR OPTIX® AQUA MULTIFOCAL (lotrafilcon B) Soft Contact Lenses* [interactive]. 2010 [previewed 2017-03-10]. Access through internet:
http://www.cibevision.com
42. Dr. Michael Blaber: *Lecture 2. Spectrophotometry* [interactive]. 2004 [previewed 2017-03-20]. Access through internet:
http://www.mikeblaber.org/oldwine/BCH4053l/Lecture02/Lecture02.htm
43. Jon H. Hardesty, PhD and Bassam Attili, PhD. Spectrophotometry and the Beer-Lambert Law: An Important Analytical Technique in Chemistry. *Department of Chemistry* [interactive]. 2010 [previewed 2017-03-24]. Access through internet:
http://vfsilesieux.free.fr/1Seuro/BeerLaw.pdf
44. Life.nthu.edu:*Beer-Lambert Law* [interactive]. [Previewed 2017-03-25]. Access through internet:
http://life.nthu.edu.tw/~labcjw/BioPhyChem/Spectroscopy/beerslaw.htm
45. Ocean Optics: *USB4000-UV-VIS* [interactive]. 1989-2017, [Previewed 2017-04-02]. Access through internet:
https://oceanoptics.com/product/usb4000-uv-vis/
46. Seijiroyazawaiwai: *LM-1200 / 1000(P) Auto Lensmeters* [interactive]. 2005 [Previewed 2017-04-12]. Access through internet:
http://www.seijiroyazawaiwai.com/wp-content/uploads/2016/08/NidekLens%C3%B3metro-autom%C3%A1tico-LM_1200-LM-1000P.pdf