

WATER POLLUTION BY SPECIAL WASTE

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ABSTRACT

The environmental impact of special waste was determined using bioindication method. The results show that even small concentrations (1-2%) of shampoos in the water cause total loss of zooplankton and phytoplankton and most of bacterioplankton, indicating the risk of shampoos use. To assess contaminants leaching from waste to water, landfill simulation reactors were used to simulate conditions over several decades. The metals' weight in the input and output waste was compared. The lowest leaching rate was found for lead, while the highest was found for cadmium and chromium. Besides, it was confirmed that the degree of leaching depends on the humidity and organic matter in the landfill: the higher the organic matter, the more heavy metals are leached from the waste. Besides, the system was developed allowing to control light scattering characteristics for environmental monitoring of natural water-disperse media, measuring of brightness at different observation angles under deep-regime conditions, building spatial scattering indicatrix, which makes it possible to determine the ecological state of the water object and the nature of pollution processes.

Keywords: special waste, shampoo, hazardous household waste, bioindication, heavy metals, leaching, water, pollution, water monitoring

INTRODUCTION

Environmental pollution by waste is one of the key environmental challenges. The increase of the world's population and technological progress cause an increase in not only waste amount but also its diversity. To a large extent, this also applies to so-called special waste – the waste requiring special treatment other than household waste. Special waste usually include hazardous household waste (batteries, fluorescent lamps, medical waste, residues of liquids used at households – paints, varnishes, cosmetics, etc.), as well as waste electrical and electronic equipment.

This study evaluates the impact of special waste on water environment by bioindication method using shampoos as a case study. The growing use of shampoos containing dangerous components poses a danger to human health and the environment. Numerous studies confirm this. According to [1], more than 13000 substances may not be used in cosmetic products, and around 250 compounds may be used only under certain conditions. In the studies [2–4], the presence of dangerous ingredients in shampoos in quantities posing a risk was investigated. Besides, under certain circumstances, shampoo components not having significant toxicity can

be transformed to more dangerous compounds. For example, Regueiro et al. [5] investigated the possibility of converting triclosan to toxic chlorophenols, dioxins or methyltriclosan. The largest study was conducted by the authors [6], which analyzed about 500 cosmetic products. The results indicate a significant risk to the environment: the predicted concentrations of many chemical compounds contained in cosmetic products (benzophenone, diethylphthalate, butylparaben, triclosan and others) exceed the limits for surface water. Similar results were obtained in [1] as well. There are studies of the environmental impact of cosmetics by various methods, including the method of bioindication [7–9], which show the negative impact of cosmetics on living organisms. The advantage of the bioindication method is that it shows the effect of various substances directly on the life and development of organisms. The quality of the environment should be assessed not only by concentrations of pollutants, but also by the final effect: the presence or absence of toxic effects on living organisms. Different organisms are used for ecological research by the bioindication method: Cladocera – to study the effects of detergents [10], Chlorella algae – to study the influence of hazardous components entering the water [11], microorganisms Daphnia and algae Ulva lactuca – to study the effects of certain species of surfactants [12–14], diatoms and other algae were used [15] to assess the overall pollution of water bodies. The study [13,16] also prove the toxic effect of surfactants on phytoplankton.

Besides, heavy metals are known to be one of the main pollutants in special waste. According to rough estimates, decomposition of electronic waste annually produces more than 40 kg of mercury, 160 kg of cadmium, 260 tons of manganese compounds, and 400 tons of other metal compounds entering the aquatic environment. Moreover, these metals can undergo various uncontrolled reactions in aggressive landfill environment followed by unpredictable formation of hazardous chemicals. Therefore, to assess the environmental risk of aquatic environments pollution by special waste, the degree of heavy metals leaching from waste was estimated using batteries as case study.

Water pollution control is also important. There are many papers [17–19] dedicated to the identification of the most significant polluting substances and to the development of high-quality devices for measuring their concentration in the aquatic environment. The relevance of such research is evident because these devices could help to control a huge amount of substances that are dangerous for the environment. The need for such approach is also due to the fact that each year the number and location of pollution sources varies. This leads to decreasing of surface and underground water quality. Therefore, there is a need for in-time detection and evaluation of new sources of pollution. To ensure proper environmental control of water quality, it is necessary to measure the pollution parameters and to have criteria for making decisions about environmental pollution by this parameter.

METHODS AND EXPERIMENTAL PROCEDURES

To study the effect of dangerous components of cosmetics on living organisms in water environment, the bioindication method proposed in [20] was used. It is based on determining the change in the intensity of algae reproduction under the influence of toxic substances contained in the aquatic environment. Short-term biotesting (96 hours) allows to determine the presence of acute toxic effects on algae, and long-term biotesting (14 days) indicates the presence of chronic toxic effects. In the environmental analysis, the detection of chronic effects is more relevant, as the constant presence of pollution leads to constant exposure. Therefore, a 14-day study was conducted. Chlorella unicellular algae was used a testing object. For the cultivation of Chlorella, 1.5 liters of pond water was sampled and provided with a nutrient medium ($\text{KNO}_3 - 0,025 \text{ g/l}$, $\text{MgSO}_4 \cdot 7\text{H}_2\text{O} - 0,025 \text{ g/l}$, $\text{KH}_2\text{PO}_4 - 0,025 \text{ g/l}$, $\text{K}_2\text{CO}_3 - 0,0345 \text{ g/l}$, $\text{Ca}(\text{NO}_3)_2 - 0,1 \text{ g/l}$). 10 samples were prepared from the test water with adding 5 shampoos in different concentrations (1 ml and 2 ml per 150 ml of water) and 1 control sample did not contain any shampoo. The samples were stored in a lighted place for 14 days. Afterwards, a visual examination of the samples was performed using Biolam P-16 microscope (magnification 400 times).

To assess heavy metals leaching, mixed household waste was used. Approximately 3 m³ of waste was manually separated into 11 fractions: metal, glass, hazardous waste, rubber, wood, food waste, paper, plastic, textile, construction waste, and residual waste. The condition of the three waste fractions listed first were not conducive to proper measurement. The metal fraction contained only steel and aluminum cans and any heavy metals inside the inert glass were mostly immobilized. Heavy metals in these fractions are therefore considered to be negligible, relative to the other fractions. The fraction of hazardous waste was represented by batteries and the metals content was calculated using literature data and masses of batteries found in municipal waste. The concentrations of 4 selected heavy metals (lead, cadmium, nickel, chromium) and of total organic carbon (TOC) were measured in each fraction by graphite furnace atomic absorption spectrometer (ZEEnit 600, ANALYTIK Jena AG) and TOC-L Analyzer (Shimadzu), respectively. The ability of heavy metals to leach from waste was estimated in the following manner. Two different mixtures of the separated waste fractions (see above), were prepared with the following compositions:

- (1) Metals – 3%, rubber – 3%, wood – 3%, glass – 8%, food – 20%, paper – 30%, plastic – 10%, textile – 7%, hazardous waste – 1%, construction materials – 6%, residual waste – 9% (total weight 33 kg).
- (2) Metals – 2%, rubber – 2%, wood – 6%, glass – 8%, food – 48%, paper – 10%, plastic – 6%, textile – 6%, hazardous waste – 1%, construction materials – 6%, residual waste – 5% (total weight 40 kg).

These waste mixtures were loaded into 2 landfill simulation reactors (LSR) for 3 months to simulate landfill conditions in an accelerated regime. The bottom of the reactors was covered by a 10 cm layer of boulders followed by a layer of tissue to filter the leachate. The waste mixture was then placed followed by more tissue and another layer of boulders to press the waste. To reproduce landfill conditions, the waste in the reactors was compressed, and a constant 37°C temperature was maintained in the reactors by a special isolation cover with heating pipes. Besides, to provide a natural humidity (average in European countries: 650 mm/year), fresh water was added daily to the reactors. With internal reactor diameter of 40 cm and cross-section area of 0.126 m², it was necessary to add $(650 \text{ L} \times 0.126 \text{ m}^2) / 1 \text{ m}^2 = 82 \text{ L}$ of water per year or 1.6 L per week. After 3 months, the concentrations of heavy metals and total organic carbon were measured in the output waste.

For the purpose of investigating the possibilities of pollution (incl. by special waste) control, a series of experiments using the automated control system under investigation were carried out in order to obtain the brightness bodies of water-dispersed media with different particle size of the disperse phase. The experiment involved both natural and artificial model environments.

THE RESEARCH RESULTS AND DISCUSSIONS

Impact of special waste on living organisms in water: case study of shampoos

The following 5 types of shampoos were analyzed to assess the effect on living organisms in water environment:

Shampoo No.1: Aqua, Cetearyl Alcohol, Quaternium-87, Propylene Glycol, Panthenol, Niacinamide, Prunus Armeniaca Kernel Oil, Isopropyl Myristate, Distearoylethyl Hydroxyethylmonium Methosulfate, Sodium Benzoate, Citric Acid, Stearamidopropyl Dimethylamine, Cetareth-20, Glyceryl Stearate, Parfum, Hexyl Salicylate, Benzyl Salicylate, Hexyl Cinnamal, Linalool, Limonene.

Shampoo No.2: Aqua, Sodium Laureth Sulfate, Disodium, Cocoamphodiacetate, Sodium Chloride, Laureth-2, Peg-12, Dimethicone, Citric Acid, Peg-7 Glyceryl Cocoate, Sodium Benzoate, Propylene Glycol, Peg-40 Hydrogenated, Castor Oil, Polyquaternium-10, Peg-55 Propylene Glycol Oleate, Parfum, Salicylic Acid, Niacinamide, Panthenol, Macadamia

Ternifolia Seed Oil, Peg-14M, Hexyl Cinnamal, Butylphenyl Methylpropional, Benzyl Salicylate, Linalool, Limonene, CL 15985, CL 47005.

Shampoo No.3: Aqua, Cichorium Intybus, Sodium Laureth Sulfate, Sodium C12-13 Pareth Sulfate, Cocamidopropyl Betaine, Sodium Chloride, Glycerin, Dimethiconol, Parfum, Glycol Distearete, Carbomer, Sodium Hidroxide, Guar Hidroxypropyltrimonium Chloride, Sodium Laureth Sulfate, Gluconolactone, Trehalose, Adipic Acid, Sodiumpybenzenesulfonate, PPG-12 Sulfate, Amodimethicone, DMDM Hydantoin, TEA, Citric Acid, Disodium EDTA, Peg-45M, Mica, Sodium Benzoate, TEA- Sulfate, Cetrimonium Chloride, Benzil Alcohol, Benzil Salicylate, Linalool, CL 15985, CL 19140, CL 77891.

Shampoo No.4: Aqua, Sodium Laureth Sulfate, Sodium Chloride, Sodium Benzoate, Glycerin, Cocamidopropyl Betaine, Sodium Xylenesulfonate, Cocamide MEA, Sodium Citrate / Citric Acid, Parfum, Dimethiconol, Cassia Hydroxypropyltrimonium Chloride, TEA-Dodecylbenzenesulfonate, Disodium EDTA, Sodium Oxide, Laureth-23, Dodecylbenzene Sulfonic Acid, Benzil Salicylate, Panthenol, Panthenyl Ethyl Ether, Hexyl Cinnamal. Hydroxyisohexyl, Linalool, Magnesium Nitrate, Argania Oil, Methylchloroisothiazolinone, Magnesium Chloride.

Shampoo No.5: Aqua, Glycerin, Cetyl Alcohol, Amodimethicone, CL 77891/Titanium Dioxide, Mica, Hidroxyethylcellulose, Stearyl Alcohol, Arginine, Behentrimonium Chloride, Trideceth-6, Chlorhexidine Diguconate, Benzil Benzoate, Benzil Alcohol, Linalool, Isopropyl Alcohol, Hidroxyethylmonium Methosulfate, Myristyl Alcohol, Cetyl esters, Cetearyl Alcohol, Cetrimonium Chloride, Citric Acid, Parfum, Coumarin, Hexyl Cinnamal, Glyceryl Oleate, Glyceryl Linolenate.

The characteristics of water samples with algae are given in the Table 1.

Table 1. Characteristics of samples for biotesting

No. of sample	Volume, ml	Shampoo added	Volume of shampoo, ml
1a	150	No.1	1
1b	150	No.1	2
2a	150	No.2	1
2b	150	No.2	2
3a	150	No.3	1
3b	150	No.3	2
4a	150	No.4	1
4b	150	No.4	2
5a	150	No.5	1
5b	150	No.6	2
6	150	control sample	0

The results of visual analysis of the samples with a microscope after 14 days (Table 2) show that zooplankton has died in all the samples (except the control).

Another study with use *Daphnia magna* Straus [9] showed 100% mortality of living organisms in 5–47 minutes after adding the shampoo. However, the concentration of shampoo in the samples in that study was higher (5%). Bacterioplankton was still alive only in samples 2a, 4b, 5a, 5b and 6 (respectively shampoos No. 2, 4, 5 and control sample), and phytoplankton – in samples 2a, 5a, 5b and 6 (respectively shampoos No. 2, 5 and control sample). Therefore, most of the bacterio- and phytoplankton have died. Though zooplankton is less resistant to shampoos.

Table 2. Results of visual analysis of the samples

No. of sample	Description	Presence of zooplankton	Presence of phytoplankton	Presence of bacterioplankton	Presence of small colloidal particles
1a	small colloidal particles, absence of bacterioplankton	-	-	-	+
1b	small colloidal particles, absence of bacterioplankton	-	-	-	+
2a	partially damaged phytoplankton cells, phytoplankton became 5-10 mm mucus clots with rare (10-15%) partially damaged phytoplankton cells, presence of bacterioplankton	-	15%	+	+
2b	completely destroyed phytoplankton cells, absence of bacterioplankton	-	-	-	+
3a	small colloidal particles, absence of bacterioplankton	-	-	-	+
3b	small colloidal particles, absence of bacterioplankton	-	-	-	+
4a	small colloidal particles, absence of bacterioplankton	-	-	-	+
4b	small colloidal particles, completely destroyed phytoplankton cells, presence of bacterioplankton	-	-	+	+
5a	completely destroyed phytoplankton cells, small colloidal particles and bacterioplankton	-	5%	+	+
5b	partially damaged phytoplankton cells, small colloidal particles and bacterioplankton	-	30%	+	+
6	undamaged cells of phytoplankton and zooplankton, presence of bacterioplankton	+	+	+	+

It is worth noting a clear correlation between the death of phyto- and bacterioplankton. That is, all the samples (except sample 4b) with phytoplankton survived had bacterioplankton alive as well. Comparing the effects of different amounts of shampoos added, it can be concluded that in some cases the content of shampoos significantly affected the survival rate of plankton. Microorganisms in the samples 2a and 2b (shampoo No.2) reacted differently to different concentrations of the same shampoo. In the sample 2a, where the shampoo content was twice lower than in sample 2b, bacterioplankton and partly phytoplankton have survived. In turn, all living organisms have died in the sample 2b. A similar result was obtained for pairs of samples 1a – 1b, 3a – 3b, and 5a – 5b. Difference in the pair of samples 4a – 4b may indicate that the content of the shampoo about 1% (2 ml of shampoo per 150 ml of water) was the threshold for the survival of bacterioplankton (bacterioplankton has died in the sample 4b). In the remaining samples, the microorganisms have died regardless of shampoo content. This indicates a significant negative impact of small shampoo concentrations on living organisms. This is also

confirmed by another study [14] of surfactants, which are the main potential danger in shampoos. The authors found some surfactants to be toxic at 2.5–3 mg/l concentration, which roughly corresponds to the concentration in our study.

The results show that most phytoplankton have survived in the sample 5b. One can assume this is due to the absence of many potentially dangerous ingredients (e.g., SLS/SLES, Cocamidopropyl Betaine, Propylene Glycol) in the shampoo No.5 (unlike other samples). Previous studies using unicellular green algae [16] confirm this assumption to some extent: the effect of SLES on test organisms was one of the largest. 2–3 mg/l of SLES caused 100% death of test organisms (*Scenedesmus subspicatus* algae). However, it certainly needs more research.

Water contamination by heavy metals leaching from municipal waste

To assess metals leaching from waste to water, one should measure metal concentration in the input waste. Since all waste fractions were mixed and partially decomposed at the end of the experiment, it was impossible to measure the residual concentrations of heavy metals and TOC in each fraction separately. Therefore, the input and residual weight of each heavy metal and TOC in the waste mixtures were compared (see Tables 3 and 4).

Table 3. Heavy metals in municipal waste fractions, µg/kg

Waste fraction	Pb	Cd	Ni	Cr
Plastic	40.1	0.8	–*	38.6
Textile	10.2	0.3	–*	14.0
Rubber	170	6.4	–*	1228
Wood	10.6	0.2	–*	167
Paper	7.7	0.1	–*	9.4
Construction material	6.9	0.1	–*	10.5
Food waste	4.0	–*	–*	7.0
Hazardous waste	13950**	228220**	661220**	50550**
Residual waste	19.9	0.2	–*	49.3
Mean in MSW1	226	3330	9646	819
Mean in MSW2	248	3762	10899	908

*below the detection limit

**calculated

If comparing the landfill simulation reactors used, there was a trend for all heavy metals and TOC to be leached more in LSR2. This is probably caused by higher waste humidity in LSR2 due to significantly higher content of organic (food) waste. It is known that metals are leached from the waste in a soluble form that can be ensured by moisture [21]. Besides, high content of organic waste in LSR2 has evidently contributed to lowering the pH. Average pH of the leachate was 5.5 and 5.8, respectively for LSR1 and LSR2. A low pH increases metals solubility and hence leaching [22]. The difference between the reactors in metals leaching was approximately the same, while the difference between TOC leaching was much more. This finding also relates to the content of organic waste since its decomposition is the main reason of TOC leaching. Therefore, food waste is likely to be the main source of mobile organic compounds. That explains increased metals leaching in LSR2 taking into account more food waste in that reactor. There were 76 and 265 mg/kg of TOC leached in LSR1 and LSR2, respectively. These data are consistent with previous study (120 mg/kg) [23].

Table 4. Weights of heavy metals and total organic carbon

Parameter	LSR1			LSR2		
	Input weight (mg)	Input weight excl. batteries (mg)	Residual weight, mg (%)	Input weight (mg)	Input weight excl. batteries (mg)	Residual weight, mg (%)
Pb	5.1	0.5	3.5 (69%)	6	0.4	3.4 (57%)
Cd	75.3	0.01	2.7 (3.6%)	91.3	0.01	1.8 (2%)
Ni	218.2	0	0.7 (0.3%)	264.5	0	0.5 (0.2%)
Cr	18.5	1.8	3.3 (18%)	22	1.8	2.5 (11.5%)
TOC	11.3	–	9.5 (85%)	13.9	–	7.5 (54%)

In 12 weeks, several decades of real landfill were simulated under an accelerated water regime [24]. The lowest leaching rate was noticed for lead. That can be explained by low solubility of many lead compounds even in an aggressive environment. Widespread lead compounds in household waste including oxides, sulfates, sulfides, and organometallic compounds are insoluble in water and, according to authors [25] can hydrolyze and become soluble only when $\text{pH} > 6$. Prechthai [26] has defined that 80% of lead in household waste is insoluble, which was proved by Yanful et al. [27] indicating insoluble carbonate as the most widespread lead compound in the waste. Besides, as described in previous section, most of the lead was found in the batteries (in the form of insoluble oxides and sulfates), as well as in the rubber and plastic slowly degrading in landfills. Therefore, even lower lead leaching could be expected. Theoretically, lead can be leached by dissolving its compounds in an acidic environment to form soluble lead acetate or nitrate. The higher amount of organic matter in LSR2 creates a more acidic environment and thus more favorable conditions for leaching of lead and other metals. For example, Janz [21] reported lead mobilization by organic chelate complexes. Lincoln et al. [28] have measured the highest concentration of lead in the leachate in comparison to other heavy metals when simulating their leaching from WEEE. On the other hand, Aucott et al. [29] have investigated that organic compounds have a high sorption capacity for lead, and can bind it retaining in the waste body. Also, lead leaching from municipal waste was the lowest among heavy metals studied by Qu et al. [30].

Much more chromium and cadmium were leached. First, more chromium compounds are water-soluble (for example, chromium sulfates and dichromates contained in some waste fractions) and hence can easily be leached. Secondly, other authors [26,31] consider chromium as a metal with one of the largest exchange form that can be easily leached. Since much of chromium was found in rubber, it probably remained unleached due to inertia of rubber (almost half of the total residual mass of chromium was initially in the rubber). This allows for the assumption that most chromium contained in hazardous waste (batteries) was leached. Less chromium was leached in another study [21]. The author explains this fact by the reduction of chromium (VI) to chromium (III) in acidic environment and subsequent immobilization to a low-soluble chromium oxide $\text{Cr}(\text{OH})_3$ and chromium-organic complexes.

The high leaching of cadmium can be explained by the interaction of cadmium hydroxide (the main cadmium form in batteries known to be the main source of this metal in household waste) with acids and the formation of soluble cadmium salts. It is also known that cadmium intensively forms metal-organic compounds through binding with organic matter [25]. Afterwards, cadmium metal-organic compounds can be easily leached. Also, chloride complexes may have some influence. Among the heavy metals, according to the study [25],

mobile chloride complexes of cadmium are most likely to be formed. As the potential source of chlorides in municipal waste, one may consider food waste and some types of plastic (PVC). It can be concluded that most cadmium (more than 95%) was leached from batteries as it was supposed for chromium. In another study [21], cadmium leaching from the waste was lower due to the formation of low-soluble cadmium sulfides and their subsequent sorption by solids. Cadmium may also be bound with manganese (iron) oxide or carbonates as shown in [26].

The change in the nickel content cannot be clearly interpreted. On the one hand, the residual nickel content was very low. This could mean that all the nickel was leached. For example, den Boer [32] has found nickel having the largest share of mobile forms among heavy metals in waste. Considering batteries as the only source of nickel found in municipal waste, we can conclude that all nickel was leached. On the other hand, an error might have occurred as Ni was only present in batteries and those might not have been included in the sample which was taken after leaching (nugget effect). The latter is confirmed by the insolubility of nickel compounds in batteries (nickelates, nickel oxides and hydroxides). However, these compounds can be converted in soluble nickel sulfate or chloride and leached under favorable conditions – acid environment and sufficient moisture content. Taking into account the measurements made, it is difficult to define whether such conditions have occurred. The hypothesis of nickel non-leaching is also evidenced by the fact that only 5% of nickel compounds in natural environments exist in soluble forms [25]. Besides, some studies [21,33] have shown that 99% of metals, including nickel and mercury, are not leached from waste containing e-waste, including batteries. However, leaching ability was determined by metals contained in the leachate. In fact, some amount of metals was released from the waste, but sorption processes did not allow metals to be leached by liquid.

A high importance for heavy metals leaching may have sulfur compounds contained in municipal waste, first of all in organic waste, plastic, and paper. Due to the short experimental period in the current lab-scale study, only the first acid phase in real landfill was simulated, when most sulfur is known [21] to be in the form of sulfates. The solubility of cadmium, chromium, and nickel sulfates and the insolubility of lead sulfate confirm accordingly high (for Cd, Cr, Ni) and low (for Pb) metals leaching.

If not considering the batteries, the concentrations of metals (except nickel) in the output waste were higher compared to those in the input waste. This may be explained by low metals leaching from the waste and by waste mass reduction due to the decomposition and leaching of organic matter, which is confirmed by other studies [34]. Another reason might be the binding of heavy metals leached from batteries in, for example, aluminosilicate complexes as reported by Qu et al. [30].

The heavy metals concentrations measured in the output waste after 12-week simulation (Pb: 0.13–0.16 mg/kg, Cd: 0.09–0.10 mg/kg, Ni: 0.03 mg/kg, Cr: 0.12–0.13 mg/kg) were significantly lower in comparison to those in the waste from real landfills. For example, in Greece metals content ranged from 5 (for Cd) to 50 (for Cr) mg/kg [35], and in Austria – from 50 (for Cr) to 350 (for Pb) mg/kg [36]. It should be noted that waste was sampled in the old landfills. Thus, there was more time for heavy metals to be enriched in waste body.

Heavy metals are known to be leached from landfills for hundreds of years, especially if they are bound within a mineral phase [37]. Therefore, if landfill is still in operation or after-closure procedures would not take place, and leachate is continuously generated, then heavy metals cause a long-term environmental risk.

Experimental studies of impurities in aqueous disperse media

A series of experiments using the automated control system were carried out in order to obtain the brightness bodies of water-dispersed media with different particle size of the disperse phase. The experiment involved both natural and artificial model environments.

According to the task the turbid media (milk, rosin and soap solutions) were used. They have absorption coefficient negligible in comparison with the scattering coefficient. Also the model disperse artificial (polychlorinated vinyl latex) and natural (phytolatex of Rewultex type) media were used. The following particle sizes were used: 0.0087 μm , 0.0875 μm , 0.55 μm , 0.875 μm and 5.255 μm .

The milk medium was prepared by mixing the appropriate amount of natural milk with water. In this case, the concentration of the solution from 0.05 to 5% was applied so that the conditions of the deep regime were most effectively implemented. To obtain a rosin medium, a saturated solution of rosin in alcohol was prepared. The two parts of this solution were mixed with one part of the alcohol, and then diluted with distilled water. The resulting rosin "milk" was mixed in the right amount with tap water. This method of preparation prevents coagulation of the rosin. When considering the rosin medium under a microscope, a large number of Brownian particles, as well as particles of irregular shape with different diameters were observed.

The soap medium belonging to colloidal media was prepared by dissolving soap in hot distilled water. The resulting solution was diluted with warm bidistilled water to the desired concentration, and then the medium was cooled to air temperature. PVC latex and phytol latex of Rewultex type were prepared according to the methods developed by the State Research Institute "Elastik" of the National Academy of Sciences of Ukraine.

The irradiation was carried out on the most characteristic wavelengths for the visible range: 450, 550 and 650 nm. The received experimental bodies of brightness for a wavelength of 550 nm are presented in Fig. 1.

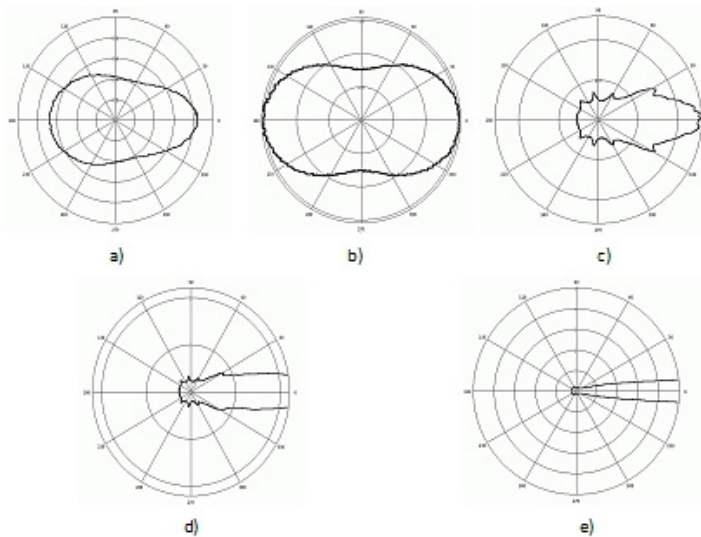


Fig. 1. Body of brightness (scattering indicatrix) of dispersed media based on PCV-latex with different sizes of dispersed particles:
a) 0.0087 μm , b) 0.0875 μm , c) 0.55 μm , d) 0.875 μm , e) 5.255 μm

According to Fig. 1, as the particle size increases the brightness body gradually shifts and extends toward the dissemination of the radiation flux. In addition, for the case of the equality of the particles size and wavelengths of the incident light, sharply expressed diffraction and interference extremes are observed. This is particularly for the angles of 30°, 60°, 100° and 135°, which coincides with the theoretically predictable mathematical models [38].

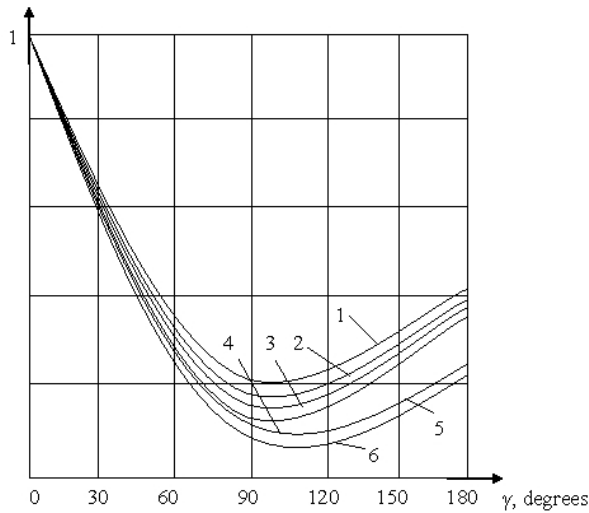


Fig. 2. Scattering indicatrix of dispersed media: 1 – seawater; 2 – river water; 3 – soap water; 4 – rosin milk; 5 – phytolates of Rewultex type; 6 – aqueous solution of natural milk.

On the basis of investigations of selected model environments indicatrix using the developed automated system, it has been proved that the patterns of radiation dissemination in the model environments are to a large extent adequate to real natural objects such as lake, sea, etc. (Fig. 2).

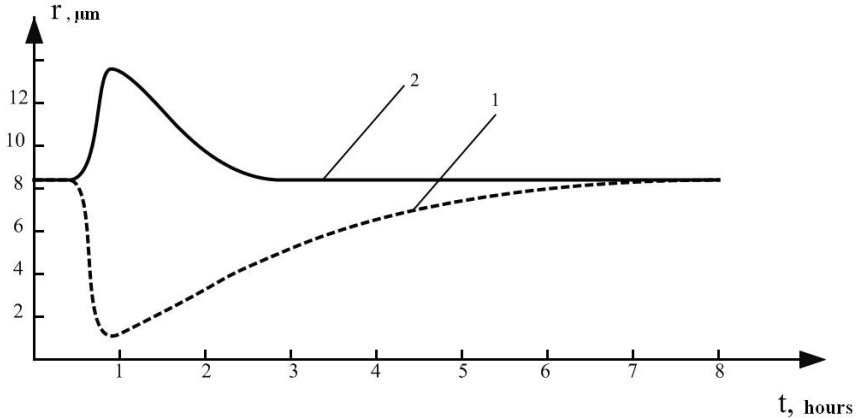


Fig. 3. Changes of contaminant particles size (r_c) in polluted water with different dispersion of pollution: 1 – $r_c < r$ of water particles; 2 – $r_c > r$ of water particles

According to the results of experimental studies, as shown in Fig. 3, it was established that depending on the size of the contaminant particles, the average particle size of the water-dispersed medium also changes. That is, in order to establish the fact of pollution at the certain time and to predict the dispersal composition of the pollutant, it is sufficient to know the disperse composition of the water environment before the pollution and to determine the average particle size of the contaminated water-dispersed medium.

On the basis of the observations results (Fig. 4), one can also concludes that the scattering indicatrix and brightness body for contaminated water-dispersed media extend with the increase of contaminant particles size. After some time after the beginning of the pollution, the pollutants start to interact with the water-dispersed medium. There are a number of physico-chemical processes of transformation, in particular, coagulation, sedimentation, etc., resulting in the changes of initial water-disperse medium dispersal composition.

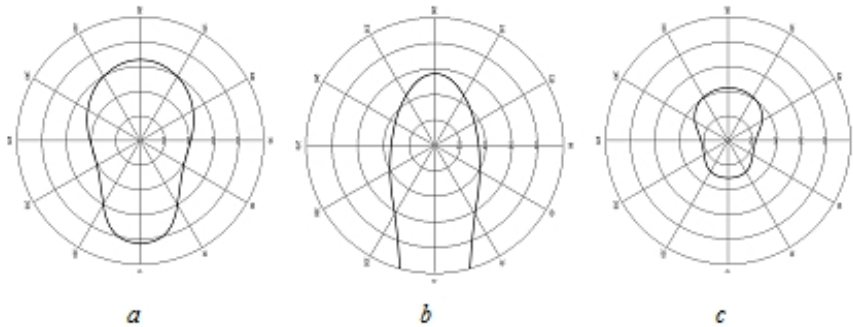


Fig. 4. Changing the scattering indicatrix: a – prior to contamination; b – after contamination with the $r_1 > r_2$; c – after contamination with $r_1 < r_2$, where r_1 is the average particle size of the contaminated water-dispersed medium, r_2 is the average particle size of the water-dispersed medium prior to contamination.

CONCLUSION

A study shows a significant environmental impact of special waste on living organisms in water environment using shampoos as case study. Even small (1–2%) impurities of shampoos in water cause total death of zooplankton and most of the phyto- and bacterioplankton within 14 days. Comparison of the shampoos of different composition suggests that the algae *Chlorella* can be most affected by surfactants SLS/SLES, Cocamidopropyl Betaine, Propylene Glycol. Some research results indicate that 1% shampoo content in water leads to total death of living organisms in most cases.

Assessment of water contamination using simulation of real landfill conditions shows higher leaching of all metals from waste fractions with a higher content of organic matter. Lead has the lowest leaching rate, which can be explained by the low solubility of its compounds. High cadmium and chromium leaching rates indicate a significant potential risk of their mobile compounds being released into the environment. Therefore, knowledge of short and long-term leaching behaviors of heavy metals may prevent contamination of the water environment or at least better assess its environmental impact when landfills are closed.

Regarding the water pollution control, the main indicators are scattering indicatrix and brightness body, which are extended with the increase of contaminant particles size for contaminated water-dispersed media. Therefore, in order to prove the fact of pollution at the certain time and to predict the dispersal composition of the pollutant, it is sufficient to know the disperse composition of the water environment before the pollution and to determine the average particle size of the contaminated water-dispersed medium.

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