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SKIN CONTAMINATION – PREVENTION AND DECONTAMINATING

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Forms of contamination

The contamination of personnel in nuclear power plants usually occurs as a result of contact with aqueous contaminated solutions and the diffusion of radioactive dust and iron particles. The latter come, for example, from the pipeline systems in radioactive plants. If this is taken into account and a detailed examination is made of the structure of human skin, measures can be drawn up to prevent skin contamination in nuclear installations as well as contaminated skin can be decontaminated from the personnel. Consequently the anatomy of skin should first be described in brief.

Structure of the skin

The skin is the communicating layer between the inside of the body and the outside world. It is an organ that provides protection against biological, physical and chemical influences of the environment. The skin, which is an organ of metabolism in man, consists of three different tissue layers, the outermost layer being constantly regenerated from inside outwards (one-way street principle). These three layers are illustrated in **Fig. 1**. They can be described as follows:

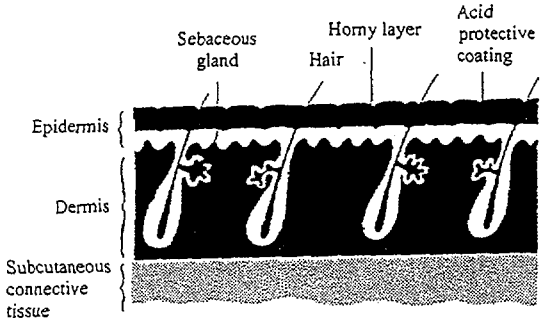

Fig. 1 Cross-section through the three layers of the human skin (Source: Fey, Wörterbuch der Kosmetik, Stuttgart, 1974)

Epidermis

The epidermis consists of four layers, namely the basal layer (stratum basale), the stratified prickle cell layer (stratum spinosum), the granular layer (Stratum granulosum) and the horny layer (stratum corneum). These layers are illustrated in **Fig. 2**.

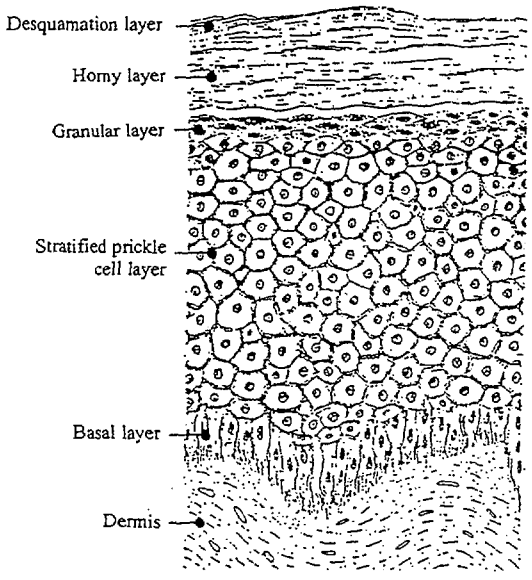

Fig. 2 Cross-section through the epidermis of human skin. (Source: Fey, Wörterbuch der Kosmetik, Stuttgart, 1974)

The epidermis is the thinnest tissue layer of the skin. It has the ability largely to prevent penetration by toxic substances from without and escape of vital substances from within and is consequently of particular interest for protection from radiation. It renews itself constantly with one of its total of 28 cellular layers in the basal layer being regenerated anew roughly every day and at the same time one cellular layer being sloughed off in the form of horny cells on the surface of the skin.

The epidermis has neither veins nor lymph vessels so the transport of substances in this tissue layer takes place as a result of diffusion processes.

Dermis
The dermis consists of the corium and the subcutaneous connective tissue.

Corium
Considerably thicker than the epidermis is the corium below it. It contains nerves, blood and lymph vessels and consists largely of fibrous proteins. These are mainly connective tissue which is made up essentially of collagen (papillary filaments, which are responsible for nutrition and metabolism) and elastin (reticulated, elastic fibres which are responsible for stability and elasticity). The elasticity and structure of the skin, i.e. whether it is young or old, wrinkled or smooth, are largely determined by the condition of the connective tissue in the dermis.

Subcutaneous connective tissue
The subcutaneous connective tissue is the layer below the dermis but differs from this in its structure. This layer contains mainly fat cells which protect the body from excessive heat loss (protection of the body from cold). Whereas the structure of the dermis resembles the firm flesh of a botrytis, the subcutaneous connective tissue has coarse pores like a sponge. By supporting the other layers of skin, it gives the skin its appearance. The subcutaneous connective tissue is riddled with an intricate mesh of vessels and nerves. When contamination occurs it is mainly only the topmost layer of skin, i.e. the horny layer that is affected. This renews itself completely about every 14 days and is on average 10µm, on the palm of the hand about 300 µm thick. The horny layer is composed of about 15 layers of horny cells (corneocytes) which are bound together with sebum, lipids and water-soluble substances. By this there is built up a membran between the horny layers to prevent the loss of humidity out of the skin.

The binding substances in the horny layer form an acid protective coating which has a pH between 5.0 to 6.5. Few bacteria, apart from occasional endogenous and specifically adapted bacteria, can live in such an acidic medium. It inhibits the growth of foreign bacteria and increases the protective function of the skin towards the body.

Processes that take place during contamination
There are known only a few reports (1-3) on the contamination and decontamination of human skin. It would be useful to summarize theses knowledge about the processes that take place on the surface of the skin so that, by taking account of the physiological and anatomical properties of the skin, preventive as well as active decontaminating measures can be drawn up for practical work in the field of nuclear engineering.

By determining the adsorption of radioactive nuclides into the horny layer using the tracer method, Pratzel, Dirnagl and Drexel (3) found that when the skin is contaminated with aqueous solutions of radionuclides only a very limited area on the surface of the skin is affected. Considerable decontamination was achieved by stripping the horny skin 5 to 10 times with adhesive. Moreover, it was established that the ability of corneocytes, which come from the upper part of the horny layer (disjunctum), to adsorb radionuclides is reduced after cleansing with washing preparations. However, this does not apply to the deeper horny layers (conjunctum) **(see Table 1)**.

Nuclide solution	Skin layers	Nuclide concentration after adsorption (mmol/g)
$59_{Fe}3+$ (134 mmol/l)	Disjunctum	
	not washed	245
	moderately washed	205
	thoroughly washed	112
	Conjunctum	
	not washed	87
	washed	97
	Suntan skin	142

Table 1 Radionuclide adsorption into skin layers' as a function of precleansing (3)

Similarly, cleansed skin is less wettable than skin covered with perspiration and metabolic products. In **Fig. 3** several drops of water have been applied to a forearm. Whereas the drops of water on the left half of the forearm which has not been cleansed have spread, they remain as discrete droplets on the right, cleansed side. Correspondingly, on the left side of the forearm pigments are more rapidly and intensively adsorbed from an aqueous suspension than they are on the right side which has been washed **(see Fig. 4)**.

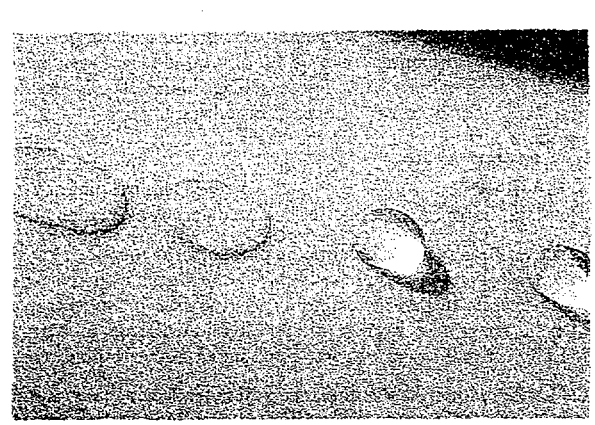

Fig. 3 Wetting of the skin on the forearm with drops of water. Rapid wetting (left) without precleansing, no wetting (right) after precleansing of the surface of the skin (5)

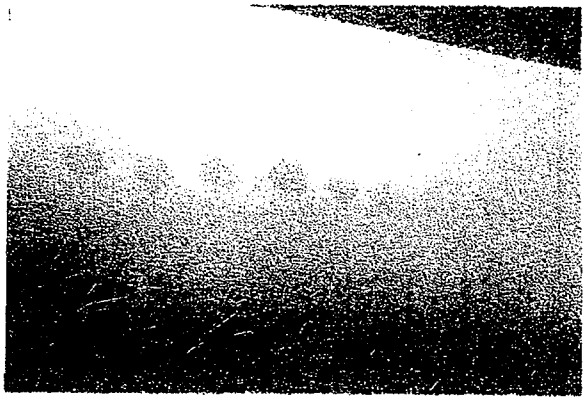

Fig. 4 Adsorption of pigments into the skin from aqueous suspensions. Good adsorption (left) without precleansing, poor adsorption (right) after precleansing of the surface of the skin (4).

These different wetting and adsorption properties of the upper horny layers are attributable to their structural composition. About half of the horny layer consists of a water-insoluble structural protein, whereas the other half is made up of water-soluble amino acids, organic acids, mineral salts, lipids and water of hydration **(see Fig. 5)**: Because of these constituents, the unwashed horny layer can be well wetted with aqueous solutions and a film of water can spread over the surface of the skin.

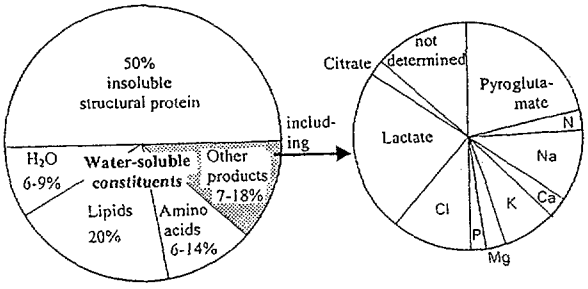

Fig. 5 Constituents of the horny layer (5)

If, however, the horny layer is first cleansed with a washing preparation, a large part of these substances is washed off. A drop of water cannot spread on the washed skin because keratin is much less wettable without these binding substances.

Considerable contamination is adsorbed after just brief contact with radioactive nuclide solutions **(see Table 2)**.

The concentration of the substances deposited in the horny layer decreases exponentially with the increasing depth of penetration (3). This means that the uppermost layers of the horny layer are more severely contaminated than the lower layers. It can be assumed that most of the solution applied to the skin corneocytes and only the little that is left penetrates vertically through the horny layer between the bases of the corneocytes **(see Fig. 6)**.

Radionuclide	Wetting time (min) 0.5	3	10-30 Amount deposited ($\mu l/cm^2$)
$22_{Na}+$	0.26	0.5	0.75
$42_{K}+$			1.1
$45_{Ca}2+$			20.0
$59_{Fe}2+$			7.0
$59_{Fe}3+$			2.4
74_{As2O3}	1.58	2.32	5.5
$36_{Cl}-$	0.26	0.34	0.72
$131_{J}-$	0.57	0.66	1.51
$32_{SO4}2-$			1.0
Salicylate ^{-14}C			3.9

Table 2: Contamination of the horny layer by aqueous radionuclide solutions as a function of the wetting time (5)

The horny skin is therefore a natural barrier which prevents liquid and especially solid impurities from penetrating into the lower layers of skin. So the risk of incorporation into the dermis in the presence of intact undamaged horny skin is very slight. (However in the event of contact with solutions of higher activity concentrations of considerably radiation dose can occur.)

Moreover it was found that the adsorption of radionuclide ions into the horny cells is reduced in the acid pH range and increased in the alkaline range. This is due to the physico-chemical behaviour of the skin surface which has an isoelectric point at about pH 4.5.

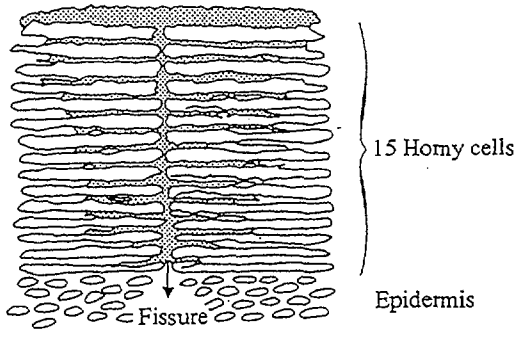

Fig. 6 Model of the diffusion of a solution into the horny layer (5). The penetration follows in time an e-function

In addition, the horny layer is destroyed in alkali by denaturing and loses its function as a protective barrier. On the other hand dehydration of the horny layer is to be expected under strongly acidic conditions and practical experience of personal decontamination has shown a pH of about 5.5 to be optimum, taking account of the pH in the acid coating of the skin. Moreover, in this pH range the water of hydration content of the skin is not impaired.

Prophylactic and decontaminating measures

In decontamination and general cleansing of the skin care must be taken to ensure that the acid protective coating of the skin and in particular the horny layer are not attacked or damaged by washing with unsuitable products. This usually happens however when the skin is washed with normal soap because soap is a relatively strong alkali and is also adsorbed on the skin (6).

As a result the acid protective coating of the skin is attacked and the horny layer partially damaged. In addition lime soap deposits will be formed, with which detached soil and contaminated particles are dragged across the entire skin during the washing process.

The following prophylactic measures are recommended to prevent skin contamination:

- Before starting work the hands and face should be cleansed with a soap-free washing preparation that is particularly gentle to the skin. This is done outside the radioactive area in a washing section within the changing room (DEKODUSCH® S or SEPTOMAN®).
- Before entering the controlled area the skin (face and hands) must be creamed with a moisturizing body lotion which will penetrate in the horny layer of skin very roughly and will leave the skin of the personnel dry and smooth (HAKALIND® Protection from contamination).
- When working in areas where there is a risk of contamination the necessary protective clothing must be worn (rubber gloves, protective goggles, etc.)
- If skin contamination is established, the skin must first be washed up to three times with a special decontaminating washing preparation under running, hand-hot water. The washing preparation must be suitable for skin and hair and must not form precipitates on the skin. The contamination must not be spread over the whole body. The decontamination washing preparation used should be clinically tested (DEKODUSCH® or DEKODUSCH® S).
- The use of a special decontamination washing paste is recommended for the removal of any remaining traces of contamination. (DEKONTAFIX®).

By systematically applying these measures a significant level of success was achieved in preventing contamination in nuclear installations. Cases where more far-reaching chemical methods had to be used were kept to a minimum.

Literature

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