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This paper explores a variety of architectural strategies that allow a secure inhabitation of radioactively contaminated scenarios after a nuclear event.

Through experiment design, existing researched methods from different disciplines currently used to manage ionizing radiation are adapted into the architectural field. The technological strategies selected for this project provide specific levels of protection against radioactivity and they cover the main mediums of the geophysical environment: air, water and soil.

The results reveal that it is possible to generate affirmative architectural solutions that can be applied in the design phase of the project using existing cross-disciplinary technical strategies that not only minimize the detrimental effects of radiation but also provide tangibility and visualization to the hazard. However, further testing is required to validate the operation and behaviour of the results in a long term exposure to ionizing radiation.

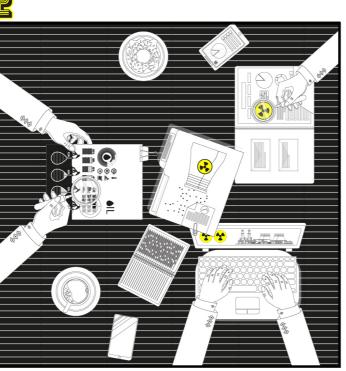
From an architectural perspective, this study emphasizes on the need of new design principles that can be used within the built environment to respond to the threats that radioactive inhospitable environments present.

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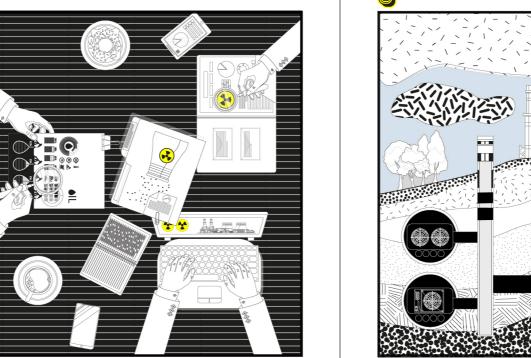
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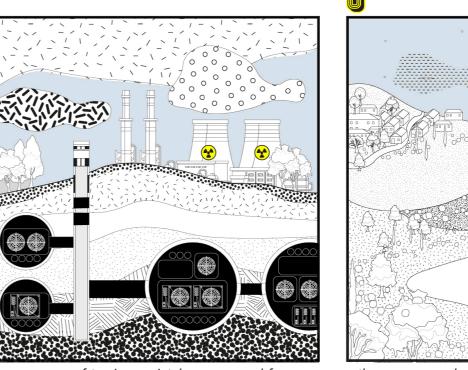
Europe reached carbon neutrality by 2052, as accorded in the Paris Agreement in 2019, and succeeded in keeping the increase of global average temperature below 1.5 °C...



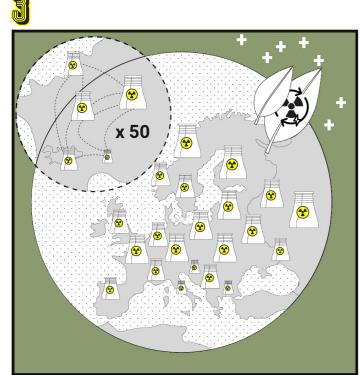
...this achievement had its roots in past initiatives of European countries that relaunched the construction of nuclear reactors in 2021 to increase the use of 'renewable energies'...



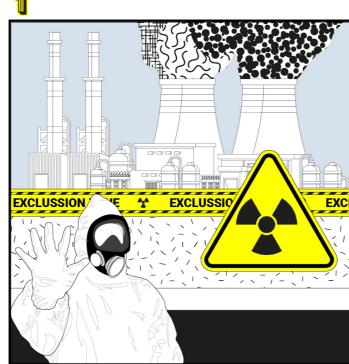
...also, as a way of taming societal pressure and fears, an auxiliary system of bunkers and tunnels were built underground in the cities close to a power plant to ensure the safety of the population in the case of an unlikely accidental event...



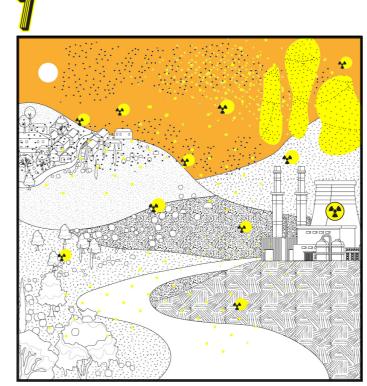
...the years passed with this new system and humanity was proud and delighted with the positive impact they were having on the environment, until the morning of the 27th of April, of 2056....



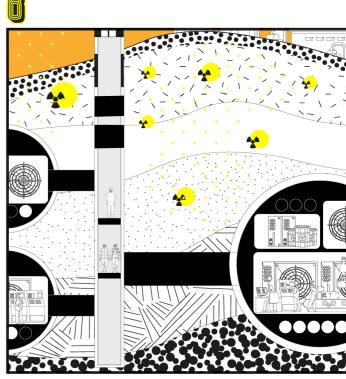
...the plan consisted in the development of fifty nuclear reactors per country with an innovative safety addition: the creation of an auxiliary net of electric power supply (Nuclear Safety Web Project) connecting all power plants...



... the NSWP was created to prevent disasters as humanity had seen in the past. It acted as a backup system to aid with possible disruptions in the electrical supply of the net...



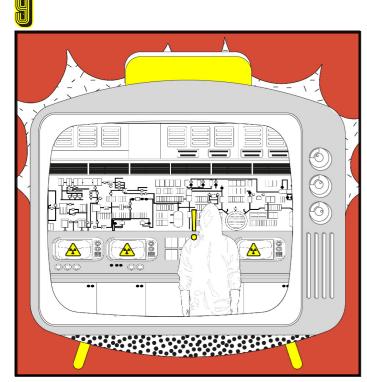
...in Cofrentes, where I have been living for the last 20 years, the day dawned covered with a dense strange looking cloud, not common for the climate of the area, that raised the alarm among the neighbours...



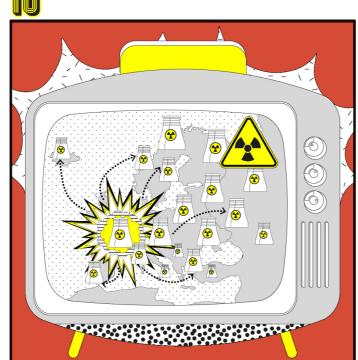
...all inhabitants of Cofrentes and the area were to immediately abandon their houses and were strongly suggested to retire themselves to their assigned bunkers, until more information was revealed...

Disclaimer: the storyboard is based on real facts. Please refer to Appendix_1 for more information.

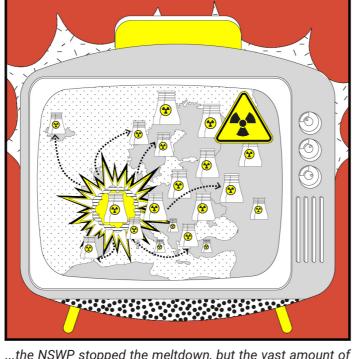
Figures 1,2,3,4,5,6,7,8. Illustrative starting scenario (own work).



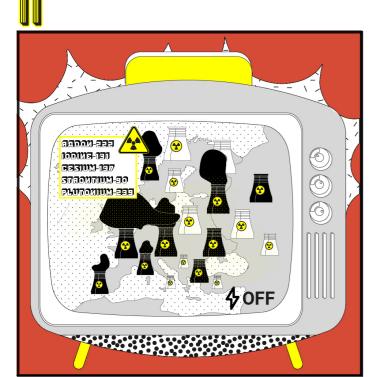
... and as of that night, safe in my tectonic underground shelter, I heard the news: The 26th of April of 2056 started as ordinary as any other day, when at 01:23:40 hours in the morning, the workers of the power plant of Blayais detected a disturbance in the supply of electrical power of that caused a loss-of-coolant situation in one of the active reactors that could end up in a meltdown...



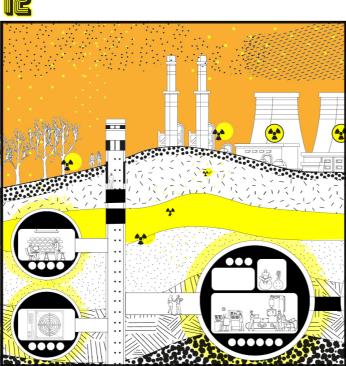
...the NSWP stopped the meltdown, but the vast amount of energy that emerged from the core of the reactor triggered a short-circuit in a section of the network, causing a chain loss-of-coolant reaction and a system overload in the NSWP. Hydrogen explosions, radioactive fallouts, and strong fire incidents continued happening in the course of two hours in



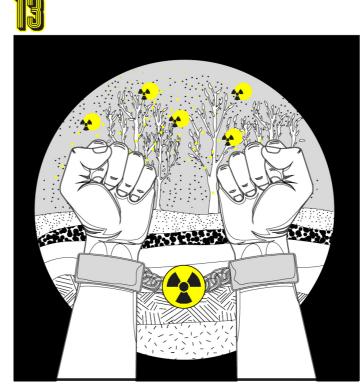
power plants in different locations succeeding one another...



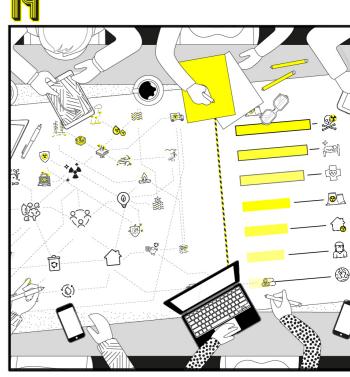
...after the accident, international experts determined the contaminants released from the cloud and the impact they could have in the environment. The radioisotopes identified in the different mediums were: Radon-222, Iodine-131, Cesium-13, Strontium-90 and Plutonium-239 distributed irregularly within the area due to atmospheric events....



... so we were recommended to stay underground, for an indefinite amount of time. Being honest, living in an underground bunker did not seem awful in the beginning. We had our basic needs met: air and water was purified with heavy machinery, we had atmospheric simulations - in order to distinguish day and night and get our vitamins from the "Sun", we were safe...

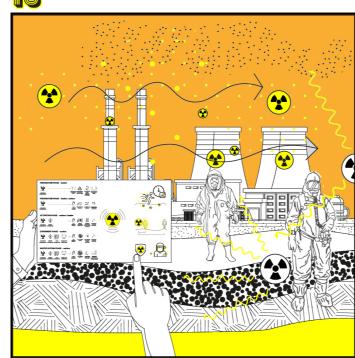


...the bunkers that were sheltering society had proved that they could protect us from radiation, but they were creating other dangers: the worst part, at least for me, was the feeling of being slaved to the geophysical environment for an uncertain period of time, and to understand that this situation was triggered by us...



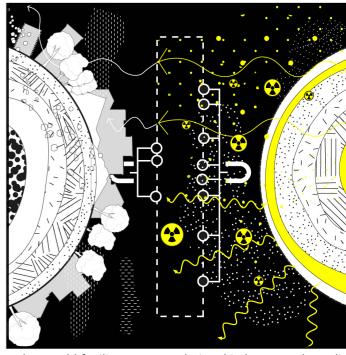
...in this scenario of resigned pessimism and uncertainty, I decided to reach to some of my neighbours in Cofrentes that were willing to try to find another way of existing within this inhospitable radioactive environment, we had to try exploring alternative solutions to go back to a life on the surface of the Earth...





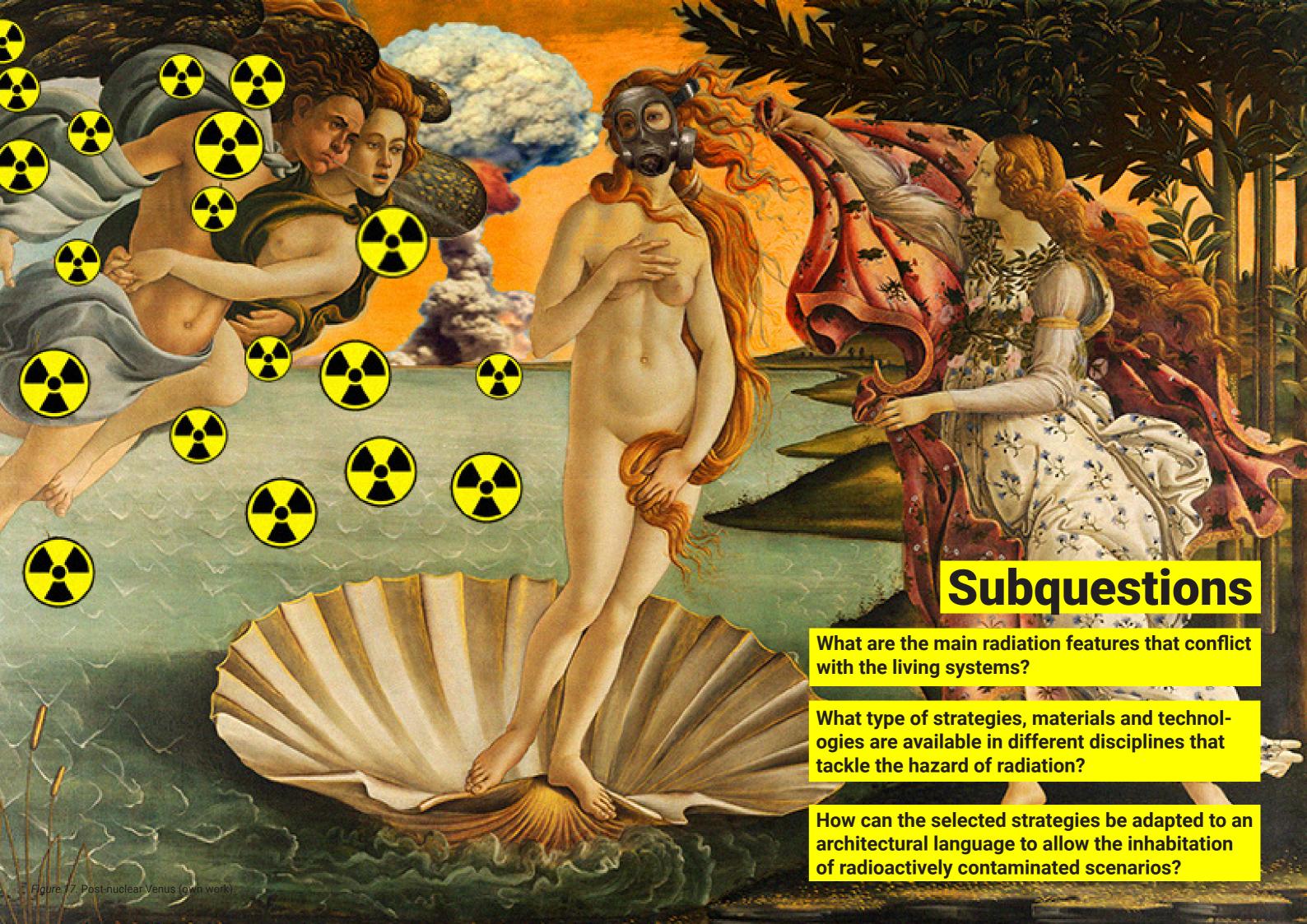
...we started by gathering materials from the nuclear power plant and the surroundings and giving them innovative uses to coexist with the radioactivity however, if we were to stablish a new settlement in this heavily contaminated area we needed to research additional architectural strategies...





...that could facilitate a new relationship between the radioactive geophysical environment and us, the living systems. In order to start the project, the main question we needed to solve was:

What affirmative strategies can be generated through Architecture to design a habitat in a post-nuclear scenario?



3. THEORETICAL FRAMEWORK

This paper addresses the topic of radiation in an affirmative approach as a rejection of the current existing architectural solutions that respond partially to the hazard. In order to achieve that position, the study starts by building up the foundations for a project between fiction and reality.

These foundations are the theoretical framework of the research, which consists on the combination of a variety of literature sources from different disciplines that contributed to the formation of the personal approach I decided to take for the project.

I have illustrated them in the literature diagram presented alongside. The sources are organized chronologically showing the connection among them as well as to architecture, and classified thematically in four categories:

- 1. Environmental issues This group of literature relates to the impact that humanity has on the resources and the equilibrium of the Earth.
- 2. Communication This literature is understood as an abstraction of the topic to gather ideas on interaction between different fields and languages.
- 3. "Dystopias" and Architecture This category grants an architectural filter to unreal or uncommon situations to nuance the personal position that is adopted for the development of the project.
- 4. Understanding radiation To understand the basics about the topic of the graduation project that will help me identify the limitations and the gaps that I can pursue in the research.

The theoretical framework is born out the conjunction of ideas and principles gathered from a variety of studies relating to not only ionizing radiation, but also reflections on our impact on the environment, non-existent realities and lastly from the power of Architectural imagination to envision future new ways of living.

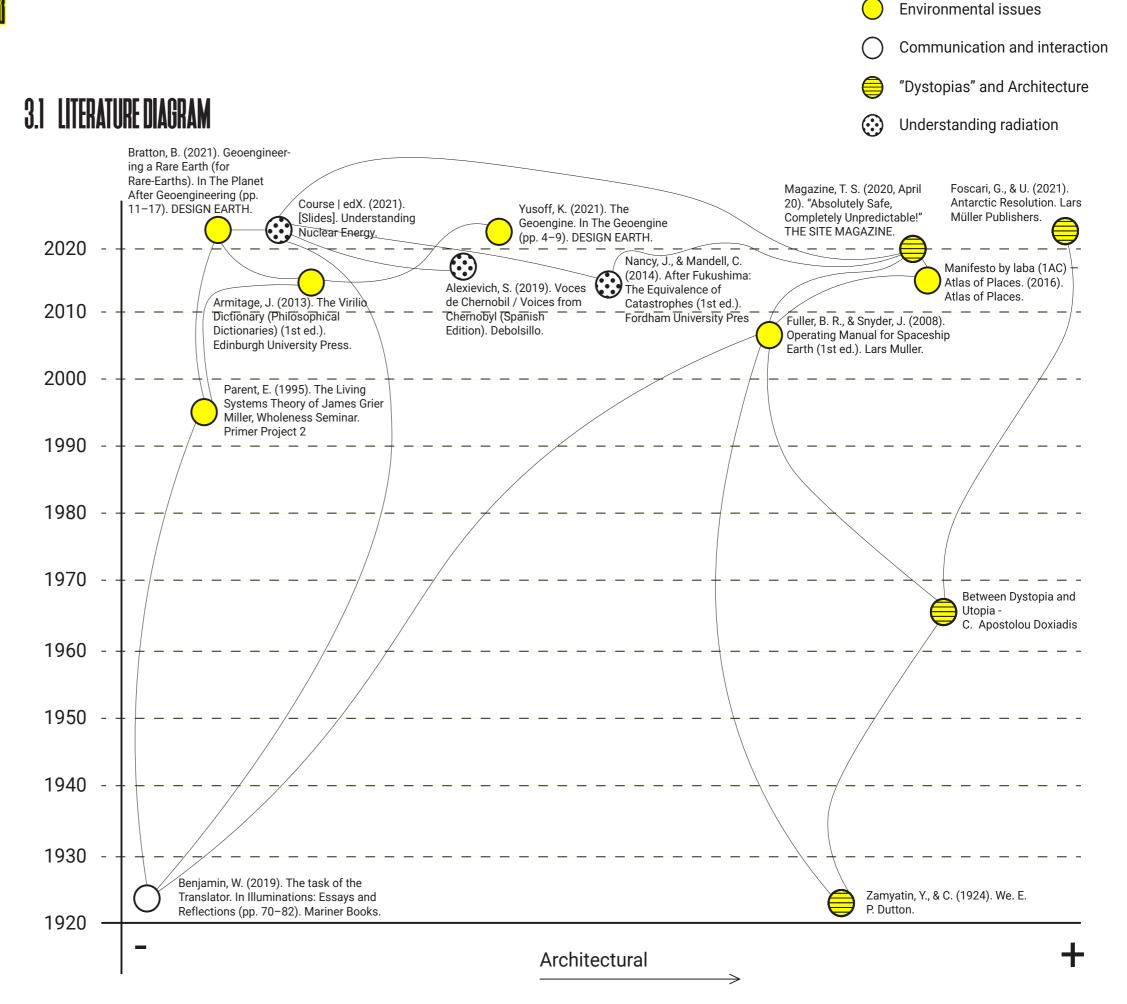
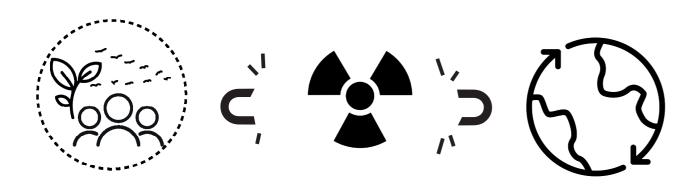
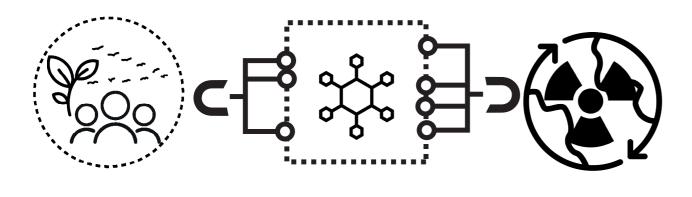


Figure 18. Literature diagram visualization (own work).

3.3 LEXICON







Architecture as a translating apparatus

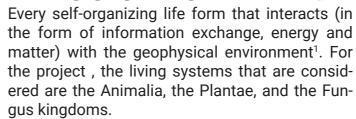
The translating apparatus focuses on generating a new relationship between the living systems and the geophysical environment after a nuclear event through affirmative strategies that allow a secure inhabitation of territories contaminated by ionizing radiation.

Figure 19. Research concept diagram (own work).

The lexicon contains definitions of terms needed to understand the research. The terms gathered have an existing connotation but in order to fit in the context of the paper, they have been nuanced.

Strictly speaking, the lexicon terminology has been created through the combination of knowledge acquired from the different literature sources presented in the previous page.

LIVING SYSTEMS



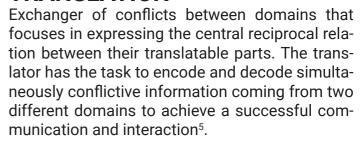
GEOPHYSICAL ENVIRONMENT

Set of conditions (physical and phenomenological) and influences in which life forms depend on and from which organisms live. Basically, a multi-functional set of layers that consist of the foundations of different interactions among living systems and the interaction of the living systems with itself²³

DEPENDENCY

The dependency of the living systems on the geophysical environment is understood as reciprocal. "Humans and their planet are not separate, human intelligence and planetary intelligence are not separate, and both are mutable."

TRANSLATION



IONIZING RADIATION

Subatomic particles or electromagnetic waves, that due to the energy they carry they can knock electrons or molecules when interacting with matter and produce a damaging effect. Main antagonist in this project, and the source of all the challenges for the living systems⁶.

SELF-SUFFICIENCY

Mode of interaction with the geophysical environment that is understood as an almost independent system focusing in food and energy production and waste management. It is a position contrary to extractivism, that focuses in a more modest use of the limited resources of the planet⁷.



- 1 Parent, E. (1995). The Living Systems Theory of James Grier Miller, Wholeness Seminar. Primer Project 2 2 Fuller, B. R., & Snyder, J. (2008). Operating Manual for
- Spaceship Earth (1st ed.). Lars Muller. (p. 57 85) 3 Armitage, J. (2013). The Virilio Dictionary (Philosophical Dictionaries) (1st ed.). Edinburgh University Press. (p. 97)
- 4 Bratton, B. (2021). Geoengineering a Rare Earth (for Rare-Earths). In The Planet After Geoengineering (pp. 11-17). DESIGN EARTH.
- 5 Benjamin, W. (2019). The task of the Translator. In Illuminations: Essays and Reflections (pp. 70–82). Mariner Books.
- 6 Course | edX. (2021). [Slides]. Understanding Nuclear Energy.
- 7 Self-sustainability. (2021, October 4). In Wikipedia.

3.4 PRINCIPLES TO RELATE THE DOMAINS OF RADIATION AND LIVING SYSTEMS

The body of the research starts by understanding the characteristics of radiation (as well as radioactively contaminated environments) and the living systems to identify which points of conflict need to be addressed through affirmative Architecture.

In order to draw comparisons between them, I am creating a hierarchical scheme that allows me to analyse within the two domains a similar level of constructive information. The idea is to identify correspondences in the inner structure of radioactivity and the living systems and that, by studying the different categories composing the scheme, I can identify the opportunities in which Architecture can act upon.

I have set for the domain four major components related to each other in a hierarchical order that are called (from a microscopic to a macroscopic order):

BASIC UNITS INTERACTIONS MEDIUMS INTENSITY

Below, I have developed a simple diagram applying the previously described hierarchical scheme to the domains of radiation and the living systems positioning in the middle the architectural translating apparatus: the goal that this graduation project aims to define.

BASIC UNITS

Smallest functional element of the domain, it determines the nature of it. A change in the basic unit, will cause complete different scenario within the domain.

INTERACTIONS

Exchange of information, energy or matter that basic units utilize to stablish a relationship between them or with the geophysical environment.

MEDIUMS

Channels within the geophysical environment in which the basic units of the domain depend on to carry interactions and stablish relationships.

INTENSITY

Set of contextual variables that determine the possibility of the existence of any interaction between the mediums and the basic units of each domain.

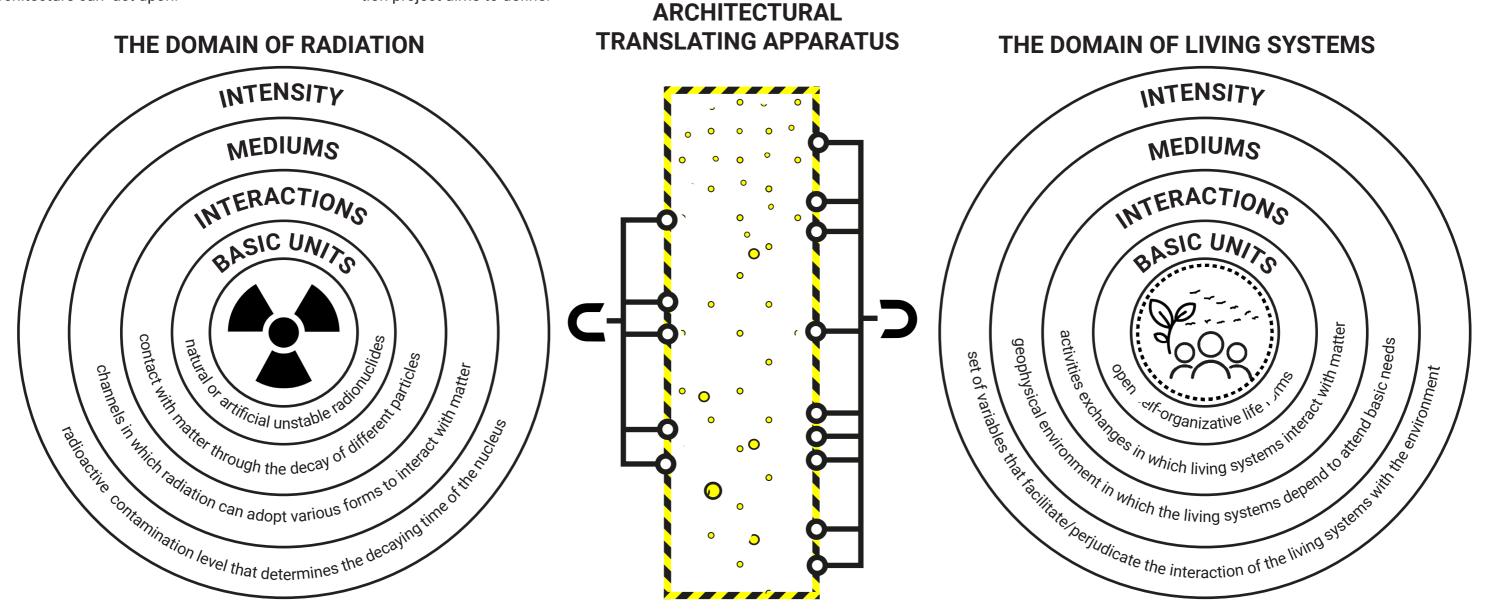
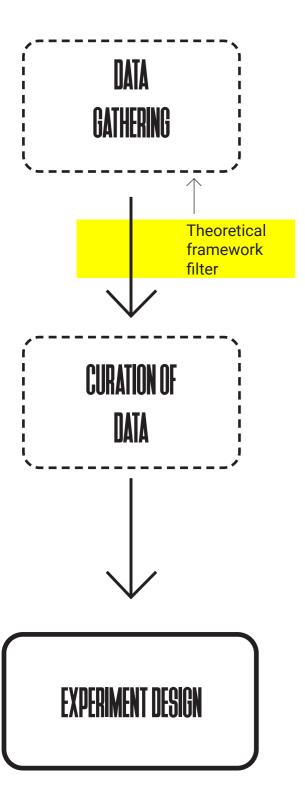


Figure 20. Relating the domains of radiation and the living systems (own work).

4. METHODOLOGY



The main approach that is adopted in this paper which will lead to the possibility of designing a habitat in scenarios after nuclear events, is experiment design.

Through experiment design, a set of curated existing technological strategies that are used in multiple disciplines within the domain of radiation are adapted to the field of Architecture. This exploration is going to involve sketching processes, digital and physical modelling and a proof of concept phase in which the researched design is going to be tested.

In order to get to the point of being able to conduct research by design, a data gathering phase is required. The analysis of a variety of sources of literature, accident precedence studies and the understanding of the basics of radiation act as a pre-study in the research to help shaping the experiment design methodology. A complementary relation between the collection of data and the theoretical framework exists: the data gathering helps shaping the framework, and the framework focuses the collection of data.

Moreover, a curation of the information acquired is needed in order to discard technological strategies that cannot be adapted into the field of Architecture.

The experiment design methodology facilitates the adoption of an innovative attitude towards the topic of this paper and allows the achievement of a grounded knowledge about the hazard of radioactivity and its effects in the living systems in which the design phase of the project can set its foundations on.

5. RESEARCH DIAGRAM

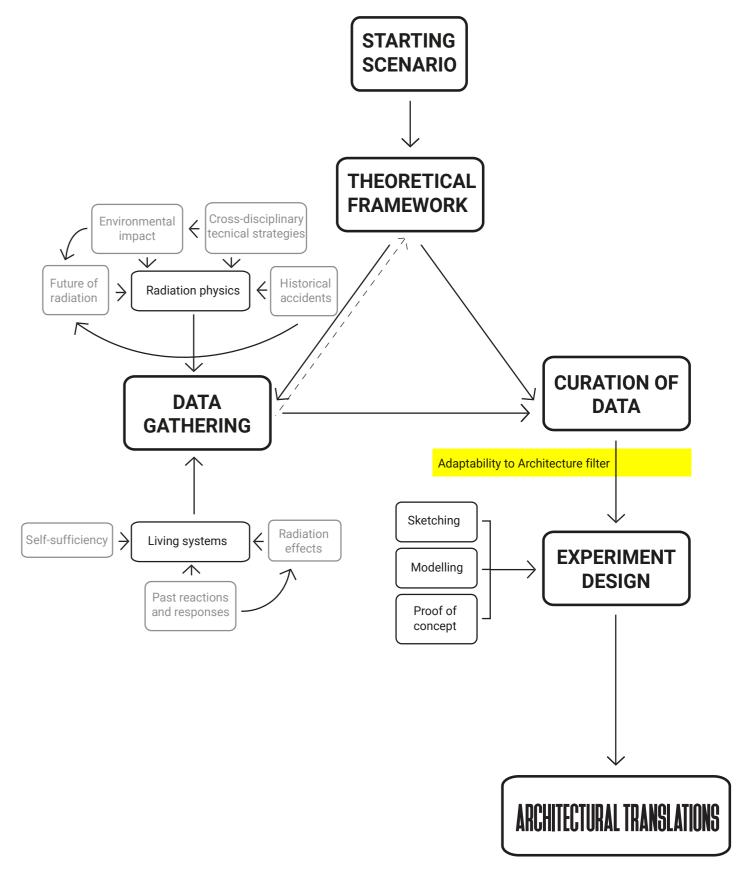


Figure 22. Research diagram (own work).

Figure 21. Methodology diagram (own work).



6.1 THE DOMAIN OF RADIATION

Basic units

In the domain of Radiation, the most basic category is defined by the different unstable radionuclides that have an excess of nuclear energy and therefore emit ionizing energy until they become stable. The radionuclides chosen for this research come from scenario storyboard. They all have a different stabilizing time that is expressed through the term half life: the time required for half of the radioactive atoms present to transform into another radionuclide. This transformation process is called decay, and it is explained in the next paragraph.

Interactions

Radioactive decay is the process in which the unstable radionuclides emit excess energy in the form of subatomic particles or high energy waves until they become stable. Each decay type has different properties when interacting with matter, reach and penetrating power^{10 11}.

 $\left(\alpha \right)$

heavy particles, short range (2-10cm in air), low penetrating power.



high speed electrons, bigger range (4 m approx.), more penetrating power

Υ

high energy photons, no mass, biggest range (10m approx.)

RADON-222

Decay particle: α Half life: 3.8 days

IODINE-131

Decay particle: β, γ Half life: 8 days

CESIUM-137

Decay particle: β, γ Half life: 30 years

STRONTIUM-90

Decay particle: β Half life: 30 years

PLUTONIUM-239

Decay particle: α Half life: 24000 years

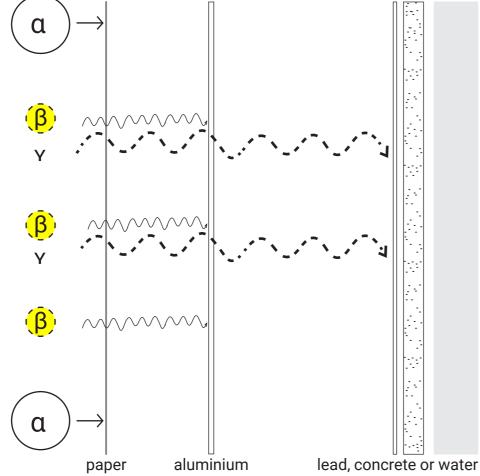


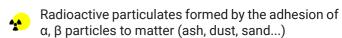
Figure 23. Types of decay and their interaction with matter (own work).

10 Course | edX. (2021). [Slides]. Understanding Nuclear Energy.

Mediums

Radiation propagates in the geophysical environment throughout the channels of air, water and soil. The radioactive decay in each medium takes up different forms and due to the connection among the channels, radiation can migrate from one to another proposing a challenge for its management.

Radioactive material that emits y particles



Radioactive gases



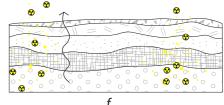
Movement caused by atmospheric and physical dynamics

· γ rac

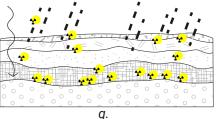
γ radiation representation

WATER **RADIOACTIVE RADIOACTIVE MATE-GASES RIAL DISSOLVED IN WATER DIRECT ENERGETIC EXPOSURE SUSPENDED RADIO-ACTIVE PARTICLES** (α, β) SUSPENDED PAR-**TICULATE MATTER** (α, β) e.

TERRESTRIAL RADIONUCLIDES



ADHERED RADI-OACTIVE PARITI-CLES (α, β)





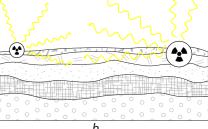


Figure 24 (a,b,c,d,e,f,g,h). Radioacitity forms of propagation in different mediums (own work)

⁸ Course | edX. (2021). [Slides]. Understanding Nuclear Energy.

⁹ Ibid.

¹¹ Neutron decay type has not been considered for this research.

Intensity

The intensity refers to the number of radioactive particles emitted by a source. It determines the level of radioactive contamination existing in a location and therefore, it is a crucial factor since the decaying time of the radionuclides and the period which will take to the mediums to stop being radioactive is proportionally linked to it¹.

The unit used to measure the ionizing radiation dose considered for this paper is the Sievert. The Sievert is a derived unit of equivalent dose, which addresses the impact and effects that ionizing radiation have on the human tissues². In short, the Sievert is a major radiation unit to express the health effects on an exposed organism.

In radiation maps, the dose rate is expressed in microsieverts per hour to determine the amount of radiation absorbed by the body by a unit of time. One of the most widely used instruments to measure the radioactive dose is the Geiger counter that detects all decay types of radiation ($\alpha,\,\beta$ and γ) and emits a clicking sound that alerts the user of the presence of the hazard³.

For the determination of the amount of radiation present in the fabricated scenario for this project, I have applied an existing map of the dose present in the area of Chernobyl after the accident to my site in Cofrentes⁴. It is worth mentioning that, the radiation levels strongly depend on the atmospheric conditions of the site: the wind moves radioactive particulates, rain causes radioactive fallouts and the soil composition of the site will determine the degree of migration of the radionuclides present in the ground. Illustrated bellow, are simulated scenarios in which the radiation has moved and migrated whithin the area.

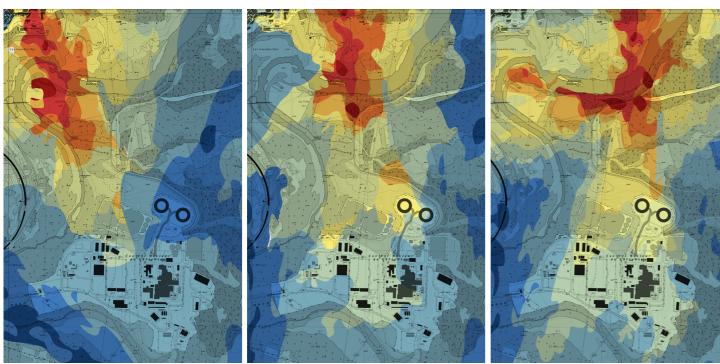
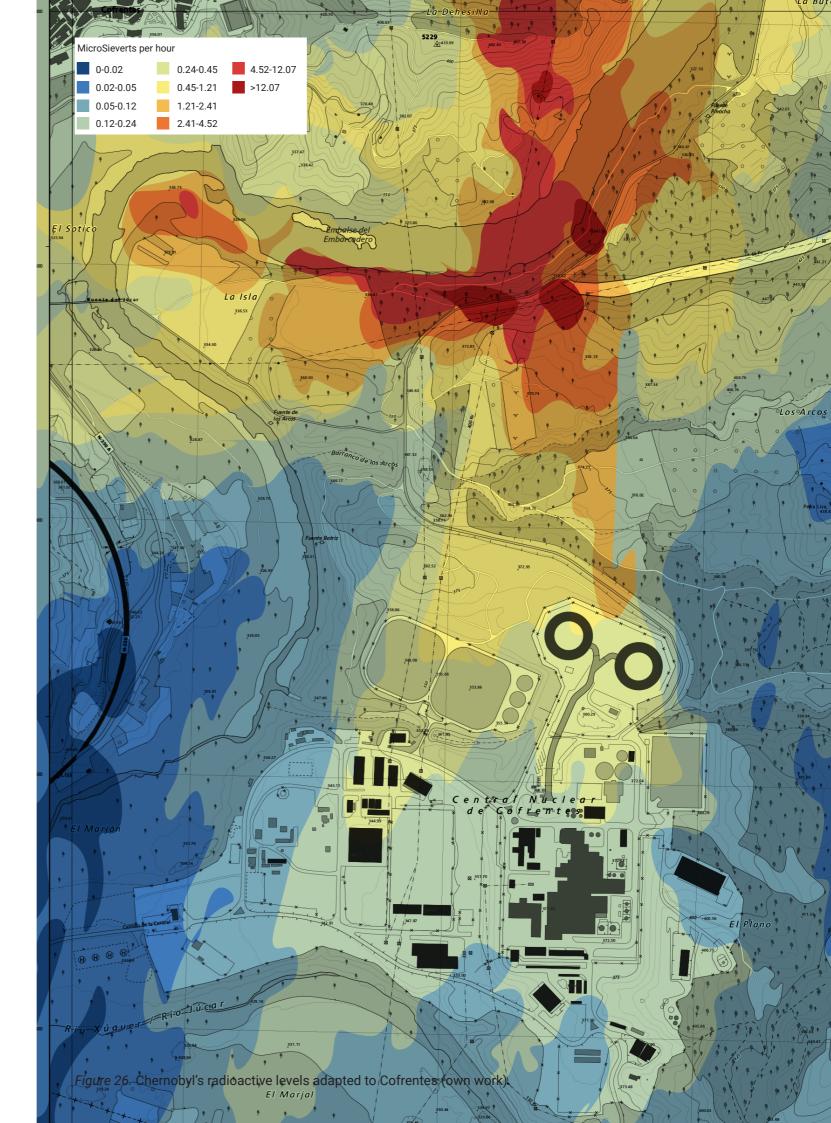


Figure 25 (a,b,c). Simulations on radioactivity levels on Cofrentes' site (own work).



¹ Course | edX. (2021). [Slides]. Understanding Nuclear Energy.

² Connor, N. (2019b, December 14). What is Sievert - Gray - Becquerel - Conversion - Calculation - Definition. Radiation Dosimetry.

³ Course | edX. (2021). [Slides]. Understanding Nuclear Energy.

⁴ See Appendix_2

6.2 THE DOMAIN OF LIVING SYSTEMS

Basic units

The first realm that forms the domain of the living systems consist of self-organizing life forms. The life forms chosen to represent this research are humans, plants and animals and, in order to focus the project, I am exploring in more depth the role of humans within this domain to determine the points of conflict with radioactivity that need to be considered to establish a non detrimental interaction.



Humans are chosen as the main study subjects for this research due to the bigger complexity of needs that they require during their lifetime.



The Plantae kingdom is going to be the nutrition form of humans.



Animals of different species are considered to aid with the resilience of the habitat.

Interactions

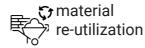
The connection that humans are going to stablish with the geophysical environment is to be self-sufficient. The choice of this interaction is justified as a response to the chain of actions that brought humanity to the starting post-nuclear scenario and the desire of a less arrogant approach to the use of resources of the planet.

SELF-SUFFICIENT SCHEME



Figure 27. Self-sufficiency components diagram (own work).







(zero) waste systems



fresh water autonomy



energy production schemes



community cooperation

Mediums

Living systems are highly dependent on the different channels of the geophysical environment. The mediums air, water and soil are the foundations on which the lifeforms rely to cover their basic needs and in the self-sufficient mode set for this project, the dependence is even higher.

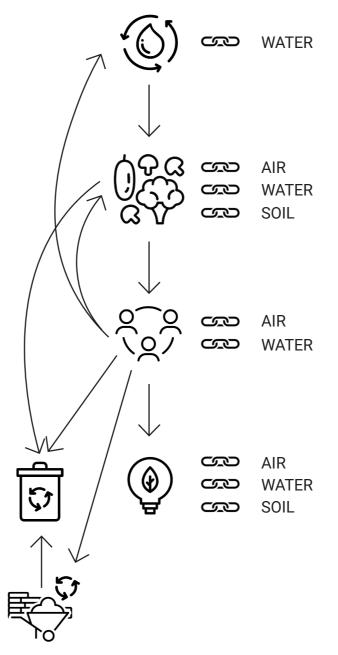


Figure 28. Diagrammatic dependencies of humans to the mediums of geophysical environment (own work).

direct dependency on medium channel chain of interactions and connections

Intensity

Set of variables that act as a filter wrapping the basic units, the interaction and the mediums. The intensity has a direct impact on the geophysical environment and the living systems and determines the level of connection between them, how this connection is happening and if it is beneficial or prejudicial. Examples of intensities are bellow:

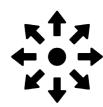
POLLUTION



Directly related with physical health: breathing, nutrition ingestion, illness

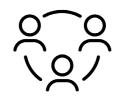
Indirectly related with psychological health: anxiety

ACTIVITY



Directly related with physical and psychological health: accessibility, connection, body wellness.

SOCIETAL FACTORS



Directly related with psychological health: community connection, traditional life, past economic activities, societal values

How radioactivity reaches living systems

This diagram explores the multiple pathways in which radioactive material reaches the living systems and cause a detrimental effect on them. Direct exposure, inhalation and ingestion are the main entrances for radiation to originate a conflict in the development of life.

The contamination pathways expose critical situations that need to be addressed in the experimental design part of this paper in order to be able to design architectural solutions for the development of a habitat that ensures the safety of the settlers.

Conflictive situations between living systems and radiation

Once the contamination pathways are studied, the conflictive situations that occur between radiation and the living systems need to be defined. These clashes are born out of the direct contact between the two domains without any protective garmet. This mode of interaction impedes any life activity from happening and is the starting point of the scenario of this research in Post-nuclear Cofrentes: the identified points of conflict need to be solved to achieve the purpose of the graduation project.

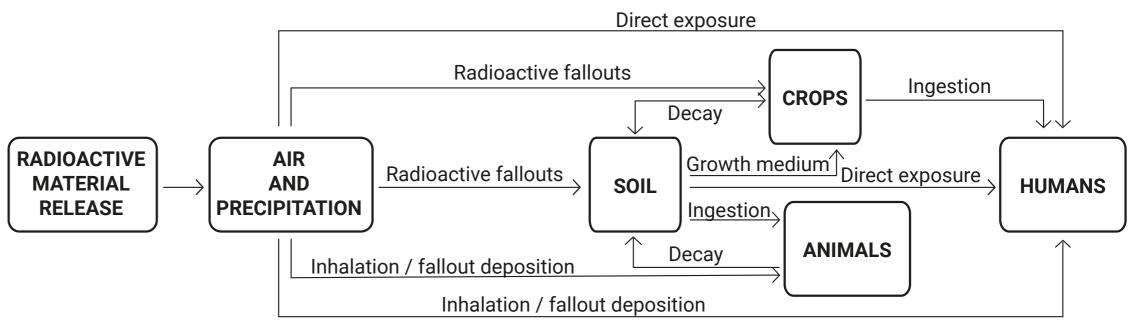


Figure 29. Pathways for radioactivity reaching humans (own work).

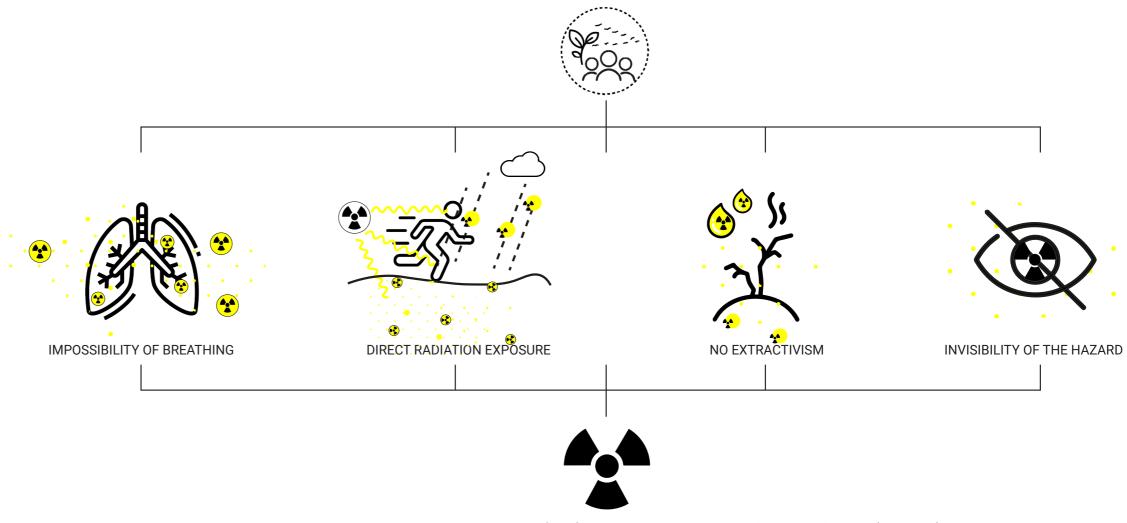


Figure 30. Diagram of conflictive interactions between radiation and humans (own work)

6.4 SELECTED TECHNICAL STRATEGIES

In disciplines related to Nuclear energy, a variety of methods are currently in use that aim to eliminate the risks that the management radioactivity originates. These methods are mainly technical strategies related to materiality, physical principles and even chemical processes.

Due to the fact that the information and knowledge gained throughout this research needs to lead to a design, a curation process of these existing technical strategies has been carried out, as explained in the methodology. Therefore, the presented elements in the adjacent table have been selected not only due to their effectiveness against different forms of radiation but also due to the possibility of adapting them to the built environment, that will result on the production of affirmative architectural responses.

The overview of strategies provide protection to different basic units (radionuclides) which present an specific interaction form with matter (α , β and γ decay types) and can cover the previously defined mediums of the geophysical environment (air, water and soil).

The different interaction modes are the following:

SHIELDING

Destined for the radionuclides that emit high energy radiation ,y rays, and for radioactive gases. The width of the material required to reduce the incident gamma energy by a factor of ten is called Tenth-Value Layer (TVL)¹ and it is a unique feature of each material. Then the total thickness of the shield will depend on the Tenth-Value Layer of the material chosen and the radiation intensity (expressed in keV)

FILTERING

Radionuclides that are α and β emitters, for which the decay particles adhere into matter (like ash, dust, sand...) require a filtering interaction. However, the filters need maintenance to avoid fouling and its malfunctioning

VISUALIZATION

Visual and sound emitter systems are selected to help the materialization of the radiation levels and alert users of the presence of risks.

INTERACTION	AIR	WATER	SOIL
SHIELDING	 DEMRON fabric Flexible and malleable fabric that provides radiation shielding properties similar to lead but with non-toxic properties. With a mass attenuation coefficient of 3.8 g/cm¹, the Tenth-Value Layer of DEMRON for 100keV of gamma energy is 0.11 cm of thickness. Radiotrophic fungi 	1. DEMRON fabric Flexible and malleable fabric that provides radiation shielding properties similar to lead but with non-toxic properties. With a mass attenuation coefficient of 3.8 g/cm ¹ , the Tenth-Value Layer of DEMRON for 100keV of gamma energy is 0.11 cm of thickness.	1. Radiotrophic fungi Cladosporium sphaerospermum fungi, found in the proximities of Chernobyl Nuclear Power Plant transforms radioactivity into chemical energy to grow. Due to this ability, it acts as a shield for other living systems. A layer of 21 cm (approx) of this material is sufficient to maintain an acceptable annual equivalent dose of radiation. ² 2. DEMRON fabric
FILTERING	1. HEPA filters High-Efficiency Particulate Absorbing filters that can capture particles as small as 0.3 microns. They are made out of a tight weave of fibreglass or polypropylene fibres that do not allow particles to go through ³ .	1. Ion exchange and granulated activated carbon filter Superposition of a layer of organic resin that removes heavy components from the water by exchanging either cations or anions from the surrounding materials and a layer of carbon activated filter, that absorbs gases and particulates ⁶ .	1. Hyperaccumulators Plants that have the ability to withstand abnormal levels of particular metals or radionuclides in their living tissues up to thousands times higher than a normal plant. They can retain contaminants in their roots, or even transport them to their leaves, making them a crucial tool for soil remediation ⁷ .
VISUALIZATION	 Scintillating material coating layer. A scintillator is a material that exhibits luminescence when exposed to ionizing radiation⁴. Plastic scintillators can be dissolved in a xylene solvent to form a film to apply in surfaces⁵. Noise emitters 	2. Noise emitters Geiger counters emit immediately at the presence of radiation a clicking sound that alerts the users.	1. Scintillator Crystals. A scintillator is a material that exhibits luminescence when exposed to ionizing radiation. In this case, the crystal is exposed to the radionuclides present in the soil. Sodium lodide is one of the most widely used scintillator materials due to its brightness8.

¹ H.W. Friedman, M.S. Singh. (2003, January). Radiation Transmission Measurements for DEMRON Fabric. Lawrence Livermore National Laboratory.

¹ X and g-RAY Tomography for the study of works of art. (n.d.).

² Shunk, G. K., Gomez, X. R., Kern, C., & Averesch, N. J. H. (2020). Growth of the Radiotrophic Fungus Cladosporium sphaerospermum aboard the International Space Station and Effects of Ionizing Radiation.

³ What is a HEPA filter? (2021, March 3). US EPA

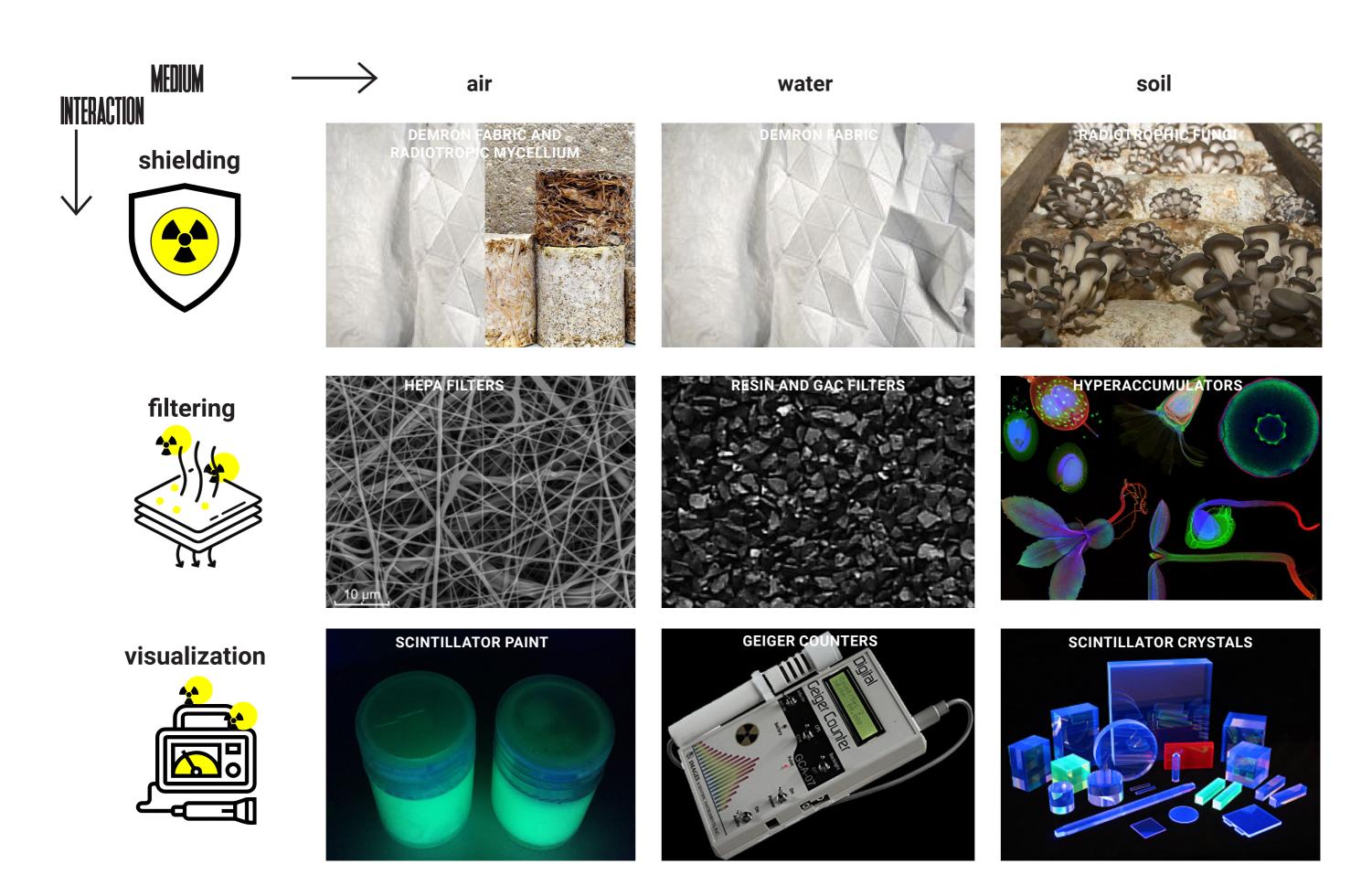
⁴ Introduction to scintillators. (2021, October 18). [Video]. YouTube. https://www.youtube.com/watch?v=Gza6Cc8XOCA

⁵ User, S. (n.d.). EJ-296 - Plastic Scintillator Paint - Eljen Technology. PLASTIC SCINTILLATOR PAINT EJ-296

⁶ McMahon, J., & Collins, M. R. (2007, March). REMOVING RADIOACTIVE CONTAMINATION FROM ION EXCHANGE RESINS USED IN DRINKING WATER TREATMENT [Slides]

⁷ Reeves, R. D., Baker, A. J. M., Jaffré, T., Erskine, P. D., Echevarria, G., & Ent, A. (2017). A global database for plants that hyperaccumulate metal and metalloid trace elements.

⁸ Introduction to scintillators. (2021, October 18). [Video]. YouTube. https://www.youtube.com/watch?v=Gza6Cc8XOCA



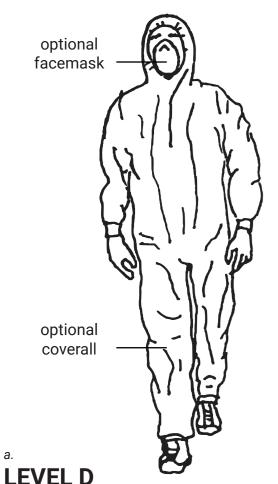
7. ORCHITECTURAL TRANSLATIONS

7.1 EXPERIMENTS FRAMEWORK

Goals

Through experimental design I intend to provide an overview of architectural translations of the technological strategies determined in the previous section that respond to the different components of the domain of radiation and can be applied in the design phase of the graduation project.

The experiments need to tackle the different mediums in which radiation can spread (air, water and soil) and need to cover the different decay types of the contaminant radionuclides: from high energy penetrating radiation (y rays) to radioactive particles (α and β).



No contaminants are present in the environment activities carried do not propose a release threat therefore only minimum protection is required.²

Design principles

The design of the experiments is inspired by Radiation Shielding Protective Clothing (RSPC) and its superposition of layers of information (in the form of technologies) with different functions that respond to variations in the radiation levels.

Priorities set up within the RSCP are organized as the following³:

- Airway protection (α and β emitters)
- Body protection (α, β and γ emitters)
- Dosimeter detectors (α, β and γ emitters)
- Cleaning of the equipment (α and β emitters)



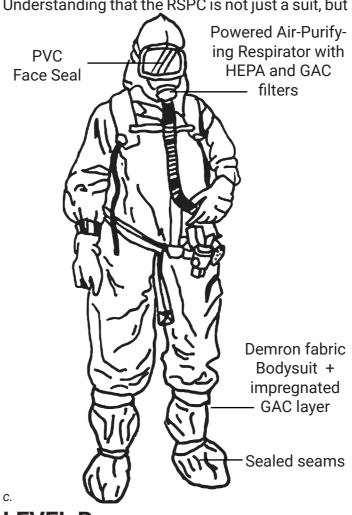
The concentration of airborne radioactive contamination is known. Basic protection is upgraded with a hazmat suit and an air purification filter.4

Protection Levels

The Occupational Safety and Health Administration (OSHA) and the Environmental Protection Agency (EPA) have established a set of response guidelines in the form of superposition of technologies that act as personal protective equipment to guard personnel from hazardous substances like radioactivity releases.

The strategies used in this personal protective equipment strongly depend on the nature and intensity of the radioactivity present in the area therefore both EPA and OSHA have determined four levels of personal protective equipment to ensure an adequate response to the hazard.

Understanding that the RSPC is not just a suit, but



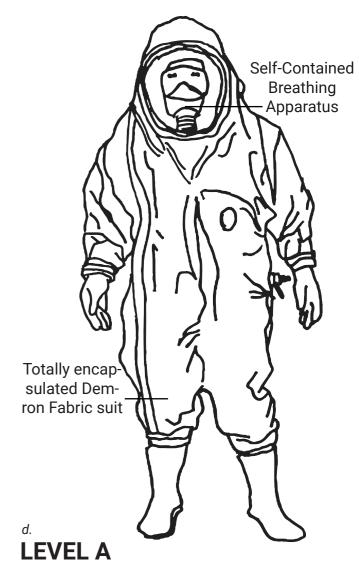
LEVEL B

The contamination levels require a higher level or respiratory protection, using Powered Air-Purifying Respirators (PAPR) and an upgrading on body shielding.5

5 Ibid.

a life support garment shaped for a human body, I am drawing a relation between the protection levels established by the EPA and the OSHA for the clothing equipment and Architecture, creating a zonification of spaces in which the activities and their use will determine the level of protection required to protect the inhabitants from the radiation hazard.

The protection levels in RSPC and their technological layering are illustrated bellow.



Required when the highest level exposure to the hazard is met. This result in a totally encapsulated protective suit and a self-contained breathing apparatus (SCBA).6

6 Ibid.

Figure 32 (a,b,c,d). Different protection levels in Radiation Shielding Protective Clothing (own work)

² Personal Protective Equipment. (2021, November 15). **US EPA**

³ Trefz, B. (2019, September 4). Equipment Selection and Use in CBRN Operations

⁴ Personal Protective Equipment, (2021, November 15)

Experiment foundations

Through research by design, the previously presented curated methods are adapted into the architectural field. The design of the experiments respond in an individual way to a set of common principles that condition the form, materiality and behaviour of the architectural translations proposed for the project:

BASIC PRINCIPLES: Set of driving forces which the experiments are based on.

INTERACTION NATURE: a non-detrimental interaction between the radioactive environment and humans can only be achieved by shielding or filtering the radioactive contamination.

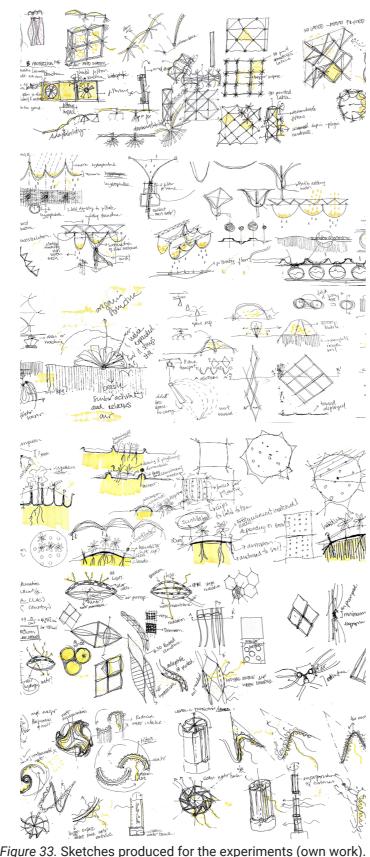
MEDIUM OF OPERATION: air, water and soil are the mediums in which radiation decay happens therefore each experiment will be focused in one medium and the form in which the decay mani-

ENERGY PRODUCTION: the self-sufficiency principle established for the habitat is going to be considered within the design of the experiments. It will be a priority to be tackled along with the radiation protection.

ASSEMBLY / DISASSEMBLY: Due the inhospitable atmosphere of the site, a limitation of exposure time during construction is preferred. The demountability of the technologies is also justified in the cases that need decontamination to avoid malfunctioning (filters).

VISUALIZATION: One of the main problems of the radioactivity hazard, is the impossibility of detection without the help of additional gadgets therefore, a driving principle of the experiments is to expose the radiation threat through a sensorial channel (auditive, visual...)

Alternatives overview: sketches



Chosen alternative to test

From the alternatives sketched, I develop further the option that respond best to the established common foundations. The information included in each experiment is:

BASIC PRINCIPLES: schematic overview of the goal of the experiment.

OPERATION EXPLANATION: The experiment is characterized/explained through the functioning and materiality of the strategy. Also, the construction process is described.

GIF: An interactive representation of the experiment is developed as a way of visualizing its theoretical operation.

PROOF OF CONCEPT VIDEO: Some experiments related to the absorption of radioactive particulates will include a video showing an initial behaviour of how the experiment can work.

RADIATION TRANSMISSION VALUE: Experiments related to shielding, include information regarding calculation of shielding thickness and materials or technical choices made.

Proof of concept video

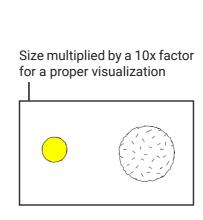
The proof of concept is understood as a way of physically demonstrating the feasibility of the experiments, to show that the concept and functioning described theoretically in the experiment design has practical potential.

The success of the experiment will be determined if the proof of concept shows a behaviour that is close to the theoretical functioning and goals.

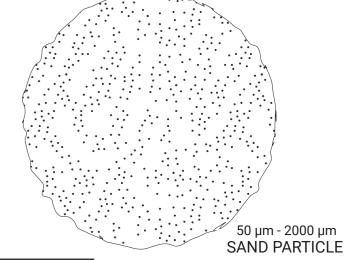
Due to the hazardous nature of radioactivity, I am proposing to test the experiments with chalk dust. This material allows the visualization (due to its colouring) of the behaviour of particles in the experiment and it is harmless to the environment and lifeforms.

The logic behind the use of chalk dust as well is that chalk particles are, in size, smaller than any dust, sand and flying ash particles 78: radioactive particulates formed by the adhesion of α and β decay particles to the previous mentioned matters are therefore bigger than chalk dust parti-

The proof of concept with this material then will prove that if chalk dust can be filtered/stopped with the technological translations, the particles described above, will be as well.



 $0.3 \mu m - 5 \mu m$ CHALK **PARTICLE** 1 μm - 100 μm DUST PARTICLE 20 μm - 25 μm FLY ASH **PARTICLE**



7 Ma, C. J., Kang, G. U., & Hamada, M. (2019). Behavior and Exposure of Chalk Dust during Classroom Teaching. 8 Lighthouse Worldwide Solutions. (n.d.). 5 Fundamentals Of Particle Counters

Figure 34. Particle sizes comparison diagram (own work).

1. Solar Shields Level _ A

BASIC PRINCIPLES

- Basic units: protection for y emitters
- Responsive to radiation intensity changes
- Solar energy production
- Fast assembly

GOAL AND FUNCTIONING

A set of inflatable layered cushions is assembled into a 3D printed structure. The demrom layers close and open depending on the radiation levels detected by the Geiger counters in the frames of the cushions. In other words, the radiation levels will determine the air that is pumped into the cushions and therefore their shielding power. A constant water layer is added to the inner part of the cushions for a more securing strategy.

RADIOACTIVE DECAY TYPE

The type of radioactive decay tackled with this affirmative strategy is high energy penetrating radiation, γ rays.

*** INTERACTION NATURE**

Shielding, meant to deflect gamma rays and due to its self-cleaning nature, radiation particles do not adhere to the surface.

★ MEDIUM OF OPERATION

Apparatus destined for aerial operation.

ENERGY PRODUCTION

Each cushion is provided with printed solar cells to produce energy.

SASSEMBLY DISASSEMBLY

The assembly of the strategy is mainly machine aided. Its demountability feature allows the maintenance of the cushions in case of failure.

*** VISUALIZATION**

The alternated patterns in the demron layers allow a variety in the aesthetics of the shields. The radiation levels are detected with the dosimeters in the cushion frame and trigger a dynamic response in them: a spike in radiation will close up the cushions not allowing any light to go through.

SKETCHED ALTERNATIVES

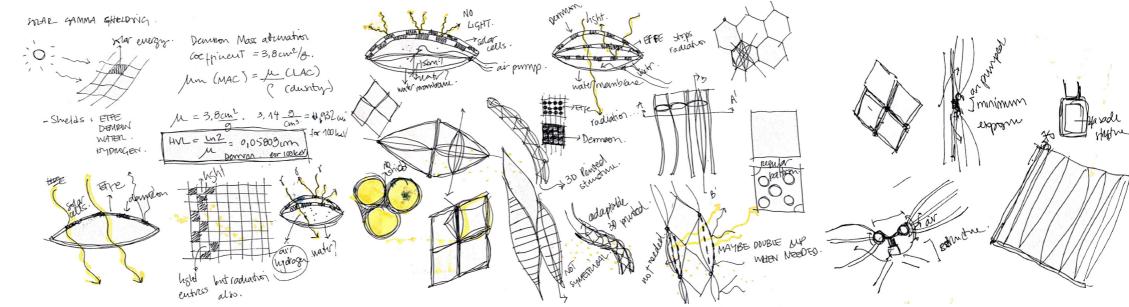
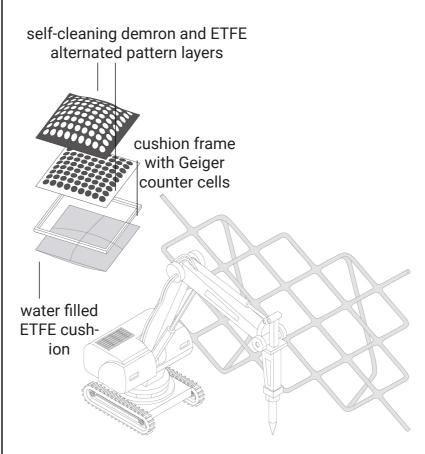
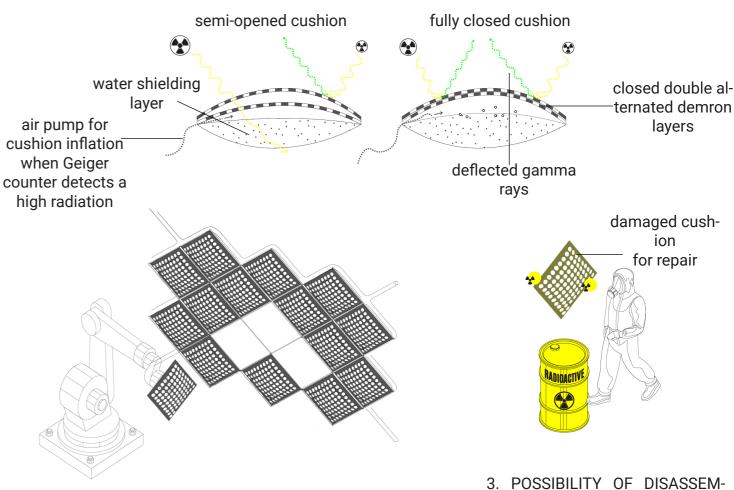


Figure 34. Solar shields experiment process sketches (own work).

CONSTRUCTION & MATERIALITY



1. 3D PRINTED STRUCTURE & CUSHION MAKING



BLING CUSHIONS FOR FAILURES

Figure 35. Solar shields construction process drawings (own work).

2. MACHINE SHIELD ASSEMBLY

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7.2 TECHNOLOGICAL TRANSLATIONS EXP 1

1. Solar Shields Level _ A

CHOICE JUSTIFICATION

Since the first thought of this experiment, I had in mind to use pneumatic architectural solutions. The flexibility of DEMRON fabric is perfect for an inflatable apparatus responsive to changes in radioactive levels. Moreover, I chose the design of a double layer option with alternated shielding patters and the reason behind this is to allow light enter the shielded spaces when the radioac-

tivity levels are not extremely high. The structure of this architectural translation is 3D printed to reduce assembly time and the rhomboid cushion alternative pods attached to the structure are chosen due to the fact that their size makes them easier to manage than bigger linear or continuous shielding surfaces. Finally, smaller shielding units can produce more flexible architectural forms when combining them.

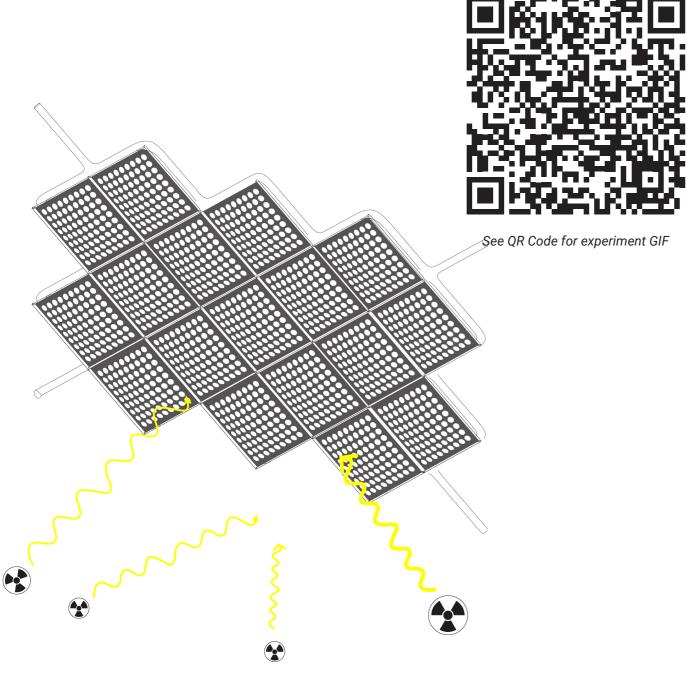


Figure 36. Solar Shields theoretical operation GIF (own work)

RADIATION TRANSMISSION VALUE

For the calculation, the radiation level considered is 600keV. This number is an approximation of the 662keV the decay of Cs-137 emmits9.

The goal is to calculate the width of the shields to reduce the gamma energy emitted up to a 10% of the measured original emission, and this is called Thenth-value Layer as previously explained.

A single cushion is composed and divided as seen bellow, with 2 DEMRON alternated pattern layers, and a volume of water.

With the TVL of the materials and the initial emitted energy, we can obtain the thickness needed.

Calculation formula TVL = ln10 / µ

TVL = tenth-value layer (cm) In 10 = 2.302585093 μ = linear attenuation coefficient (cm⁻¹) is needed for the materials of the shield: DEM-RON and water. The µ of water is obtained from an existing chart¹⁰, and the μ of DEMRON is an approximation of the µ for 100 keV¹¹ due to the fact that there is no specified information for an emitted energy of 600 keV.

The linear attenuation coefficient for 600keV

Tenth-value layers of materials for 600 keV:

$$\mu$$
 water = 0.09 cm⁻¹ μ DEMRON = 6.32 cm⁻¹

TVL
$$_{water}$$
 = ln10 / μ = 25.58 cm for 600keV TVL $_{DEMRON}$ = ln10 / μ = 0.36 cm for 600 keV

The sample thickness of DEMRON is 0.038 cm¹² therefore we need 9.47 (10) layers of DEMRON fabric to provide the protection (considering only this material).

The final chosen thickness of the shielding cushions after the calculation are the following:

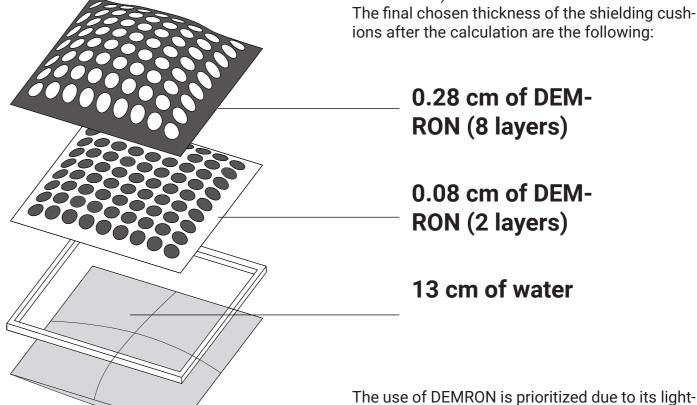


Figure 37. Extruded cushion composition (own work).

Swiderski, L. (2013). Non-proportionality and energy resolution of Xe gas scintillator in gamma-rays spectrometry. Research Gate.

¹¹ H.W. Friedman, M.S. Singh. (2003, January). Radiation Transmission Measurements for DEMRON Fabric. Lawrence Livermore National Laboratory. 12 Ibid.

2. Radiogas Pop-up Traps Level _ A *

BASIC PRINCIPLES

- Encapsulation of radioactive gases (Basic units)
- Fast response

GOAL AND FUNCTIONING

When a release of radioactive gas is detected, a drone transports the radiogas trap to the area, which pops up and expands into an encapsulating dome when it hits the soil. The space within the dome is inhabitable until the radioactive gas decays into a more stable isotope, which in the case of radon, takes approximately 4 days. A geiger dosimeter in the axis of the dome detects when the hazard is gone and the dome can be folded and stored. A level A* protection is granted due to the encapsulating nature of the strategy but questioned since the strategy does not allow habitability of the space.

RADIOACTIVE DECAY TYPE

The trap is destined to the decay of gas radioactive isotopes, which in this case is α .

***** INTERACTION NATURE

Shielding. While the dome is expanded, radioactive gas is not able to escape.

***** MEDIUM OF OPERATION

Apparatus destined for aerial operation.

ENERGY PRODUCTION

This strategy does not produce energy.

* ASSEMBLY/ DISASSEMBLY

The radiogas trap does not need assembly due to its pop up expansion feature but it does need human disassembly by folding the strategy into its original form when the hazard is gone.

VISUALIZATION

The Geiger counters located in the axis of the dome allow for an auditive recognition of when the radioactive gas is still present inside the dome.

SKETCHED ALTERNATIVES

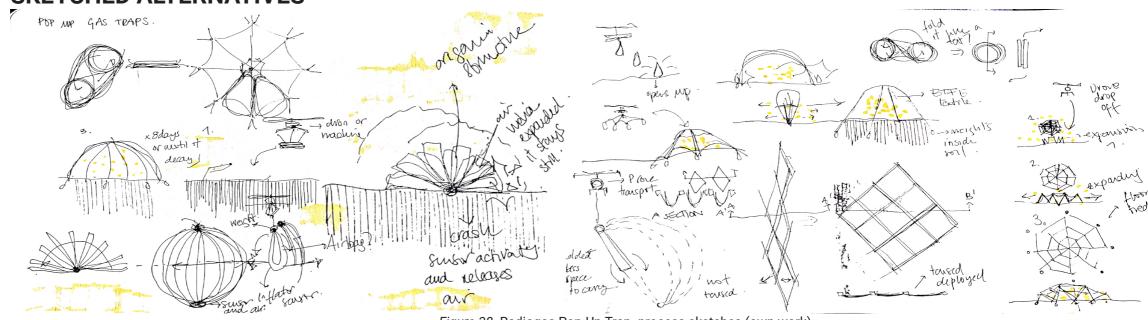
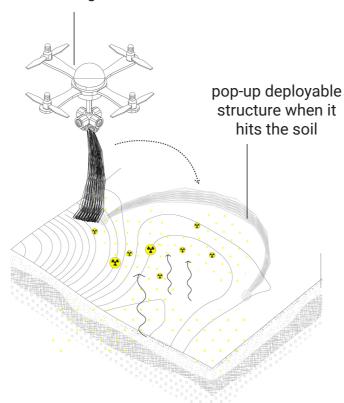


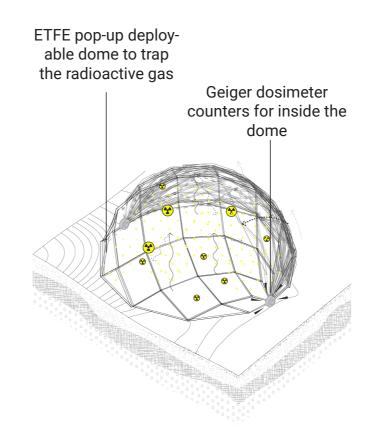
Figure 38. Radiogas Pop-Up Trap process sketches (own work).

CONSTRUCTION & MATERIALITY

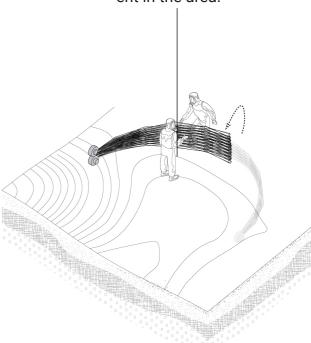
drone transportation to the radioactive gas release area



1. DRONE TRANSPORT AND DISPOSAL



structure removal and folding when the radioactive hazard is not present in the area.



2. EXPANDED TEMPORARY ETFE DOME TO TRAP RADIOACTIVE GAS UNTIL IT DECAYS

3. HUMAN REMOVAL OF RADIOGAS TRAP

Figure 39. Radiogas Pop-Up Trap construction process drawings (own work).

7.2 TECHNOLOGICAL TRANSLATIONS EXP 2

2. Radiogas Pop-up Traps Level _ A *

CHOICE JUSTIFICATION

The basic design principle of this experiment is its automatic deployability. Sketches roam around pop up possibilities inspired by sleeping tents, parachutes and origami architecture. The chosen version is inspired by the latter and the air-bag functioning. The folds that are created in origami originate a repetitive behaviour when the

structure is deploying providing a rigidity during the expansion process and when the trap is completely opened. Also, the same folds aid when the trap is being removed, making it easy for the workers. I included a Geiger counter for noise emitting in the revolving axis of the dome to help to detect radiation and to add weight points in the structure, making it more stable in the location.

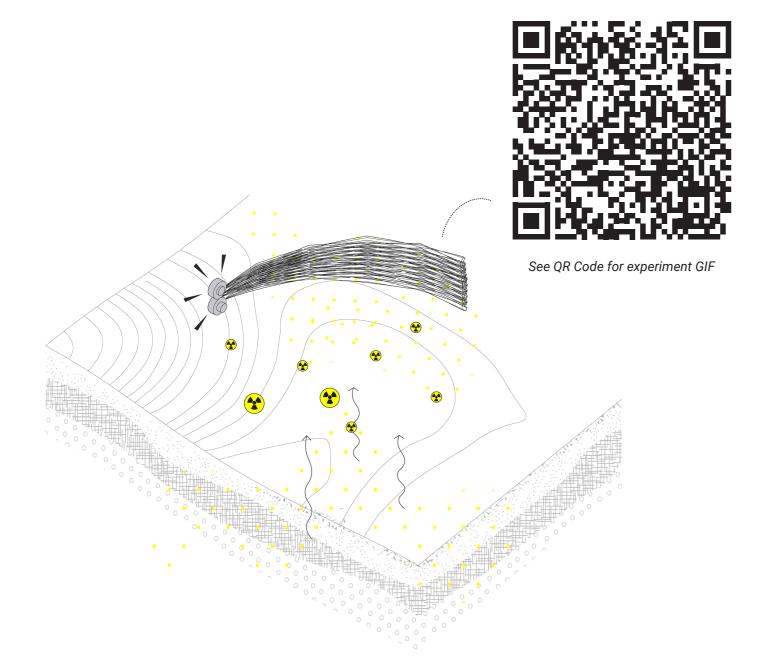


Figure 40. Radiogas Pop-Up Trap theoretical operation GIF (own work).

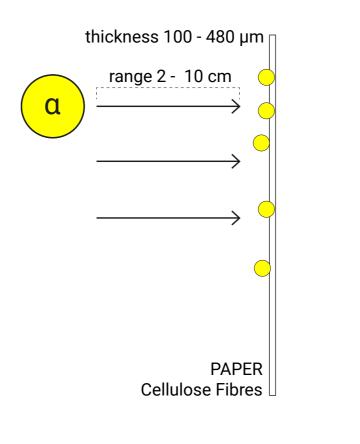
RADIATION SHIELDING MATERIAL

weight and better properties against radiation. Radon-222 , as the basic unit tackled in this experiment, is a radioactive gas that decays emitting α particles and has a half life of 3.8 days.

 α particles have the shortest range and a low penetration power. ¹³ A sheet of ordinary paper stops them from penetrating the human skin. However, even though they have a short range and they require simple shielding, they are extremely dangerous when they reach the airway systems, therefore it is crucial to provide a solution that impedes their inhalation until the radionuclide completely decays.

Even though paper solves the radiation problem, it cannot be used as a construction material since it is not resistant to atmospheric precipitations, it can easily tear and it does not allow for manipulation since it quickly degrades.

That is why I have chosen a different alternative: ETFE has been used widely in construction due to its elasticity, its light-weight, its strength and its non-stick surface that resists dirt.¹⁴



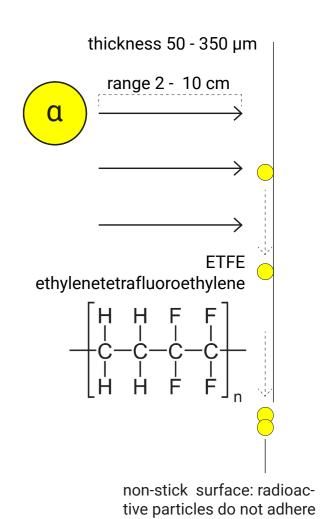


Figure 41. Alpha decay particles and matter interaction (own work).

14 ETFE, the Bubble Wrap of Building. (2018, November 20). ThoughtCo.

¹³ Course \mid edX. (2021). [Slides]. Understanding Nuclear Energy.

3. Radioparticulate collector Level _ B

BASIC PRINCIPLES

- Radioactive air/water particulates collector
- Turbine energy production
- Demountability

FUNCTIONING

A Matrix of dynamic filters, reactive to medium conditions open and close with the action of the wind or water allowing the circulation of fluid. Radioactive particulates are retained in the apparatus filters and the clean fluid is stored in an inner tank ready to be circulated into liveable spaces.

RADIOACTIVE DECAY TYPE

The types of radioactive decays tackled with this affirmative strategy are α, β particles suspended or adhered to matter (ash, sand, dust...)

INTERACTION NATURE

Filtering. Requires maintenance to avoid failure in filters (demountable to allow decontamination) due to fouling or over-accumulation of particles.

❤ MEDIUM OF OPERATION

Structure allows for the usage in air and water. The experiment detailed is destined for atmospheric operation.

ENERGY PRODUCTION

Wind and current force induce a rotation in the filters that is translated into electric energy that can be stored in batteries in case of an excess.

ASSEMBLY/ DISASSEMBLY

The demountability of the filtering parts of the experiment is a crucial feature in order to avoid particulate fouling or saturation of the filters and its consequential malfunctioning.

VISUALIZATION

The dynamic nature of the energy production pieces is destined to the visualization of the wind force and direction, to see where the main source of contamination is coming from.

The scintillating coated filters emit light when radioactive particulates are captured allowing the pioneers to know when they need maintenance.

SKETCHED ALTERNATIVES

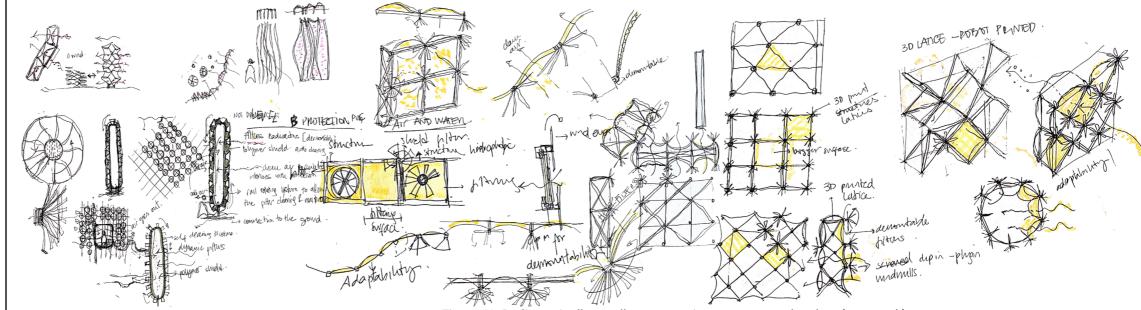
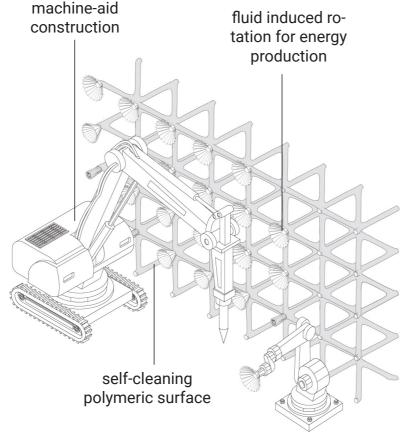


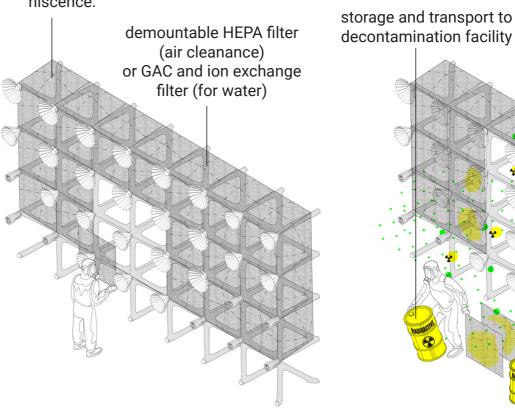
Figure 42. Radioparticullate collector experiment process sketches (own work).

CONSTRUCTION & MATERIALITY



1. 3D PRINTED STRUCTURE

Filters coated with an scintillating film for radiolumi-



2. HUMAN FILTER ASSEMBLY

3. FILTER DECONTAMINATION MAINTENANCE

Figure 43. Radioparticullate collector construction process drawings (own work)

niscence.

particulate fouling

in filter that requires

maintenance

7.2 TECHNOLOGICAL TRANSLATIONS EXP 3

3. Radioparticulate collector Level _ B

CHOICE JUSTIFICATION

From the sketched alternatives, I chose the one that had the biggest filtering surface and an easy assembly and disassembly. Secondly, the experiment integrates machine-made construction, diminishing time of exposure of workers at the beginning of the project. Another supporting reason of this formal choice is that the technical as-

pects of the strategy are completely shown and transparent, so the functioning of the apparatus is clear.

The last reason for this choice is the adaptability of the 3D printed lattice to create different forms which makes it useful for the design phase of the project and for the strategy to respond to the different mediums of operation: air and water.

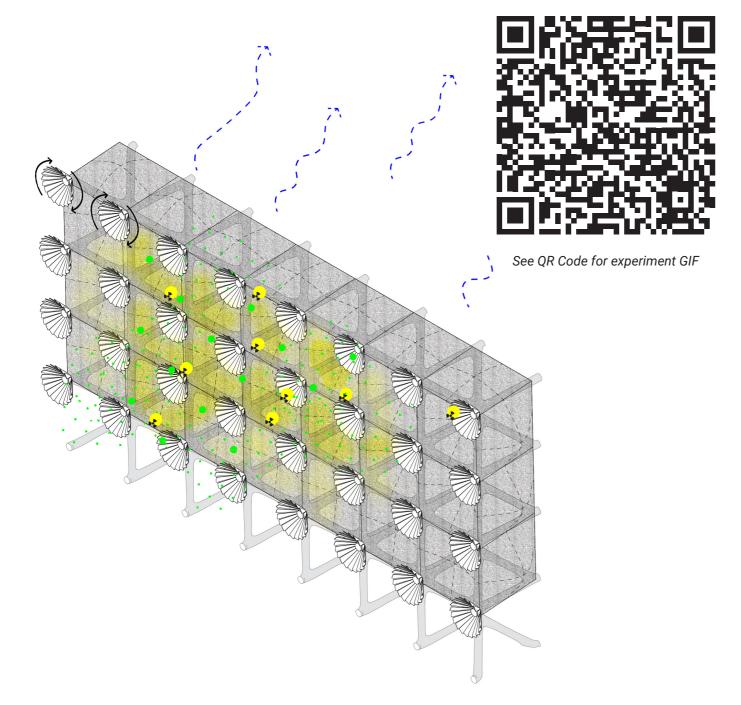
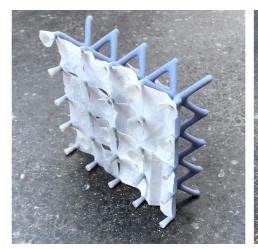


Figure 44. Radioparticulate collector theoretical operation GIF (own work)

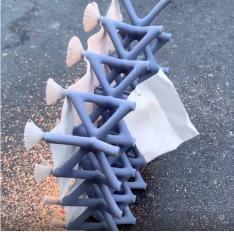
♥ PROOF OF CONCEPT VIDEO



See QR Code for Proof of concept video







The first test of the experiment proves to have a promising behaviour. The model is exposed to a wind current containing chalk particles and , as seen in the video, the filters retain the contaminants. The white fabric located behind the ex-

periment ends up clean after the chalk exposure. More testing is needed to analyse the behaviour of the filters when they reach a level of saturation, and how often they need replacement.

4. Radiomidity Harvester Level _ C

BASIC PRINCIPLES

- Collect atmospheric humidity
- Filter the suspended radioactivity particles
- Wind energy production

GOAL AND FUNCTIONING

Contaminated humidity carried in wind is captured with the help of the apparatus protrudings and filtered within the body of the experiment. Clean water travels down with the help of gravity in the inner surface of the apparatus and is stored in a water tank for future use.

RADIOACTIVE DECAY TYPE

The types of basic units tackled with this affirmative strategy are α , β emitters in which particles are adhered to matter (ash, sand, dust...)

★ INTERACTION NATURE

Filtering. Requires maintenance to avoid failure in filters (demountable to allow decontamination) due to fouling or over-accumulation of particles.

*** MEDIUM OF OPERATION**

Apparatus destined for aerial operation.

ENERGY PRODUCTION

Wind force induces a rotation within the vertical axis aided by the slightly curved filters. Electrical wind power is stored in batteries for later usage.

***** ASSEMBLY/ DISASSEMBLY

The demountability of the filtering parts of the experiment is a crucial feature in order to avoid particulate fouling or saturation of the filters and its consequential malfunctioning.

VISUALIZATION

The filtering parts are coated with a scintillating film in order to emit light when radioactive particulates are captured allowing the pioneers to know when they need maintenance.

SKETCHED ALTERNATIVES

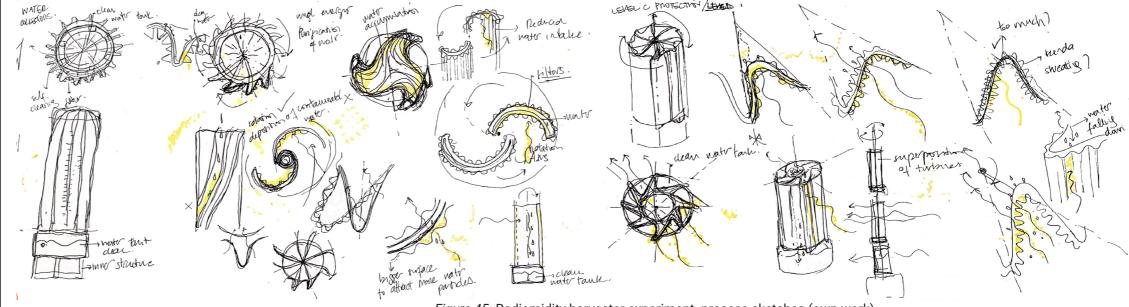
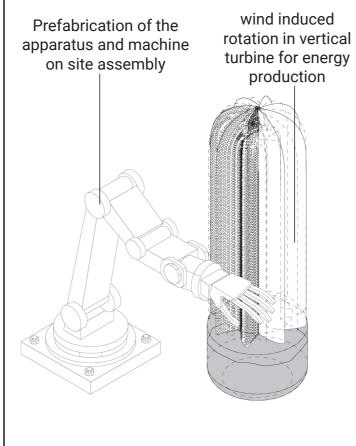


Figure 45. Radiomidity harvester experiment process sketches (own work).

CONSTRUCTION & MATERIALITY



1. MACHINE AID ASSEMBLY

demountable granulated activated carbon filtering structure

storage and transport to decontamination facility

surface coated with an scintillating film for radioluminiscence.

demountable clean water tank

clean water tank

3. FILTER DECONTAMINATION MAINTENANCE

Figure 46. Radiomidity harvester construction process drawings (own work).

2. CLEAN WATER STORAGE HARVEST

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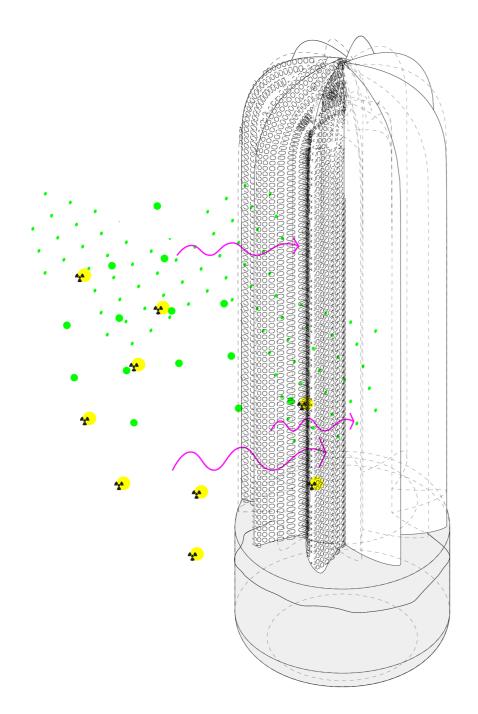
7.2 TECHNOLOGICAL TRANSLATIONS EXP 4

4. Radiomidity Harvester Level _ C

CHOICE JUSTIFICATION

For this experiment, the research by design started by considering forms that would aid the production of electrical energy from wind. In addition, since the other basic principle is the obtention of water from atmospheric humidity, I had to provide as much filtering surface as possible.

Therefore, inspired by how cactuses obtain water in dry environments, I considered the best option would be design a biomimetic strategy with a slight tweak in the filtering components in order to get the rotation movement needed to produce electrical energy.





See QR Code for experiment GIF

Figure 47. Radiomidity harvester theoretical operation GIF (own work).

♥ PROOF OF CONCEPT VIDEO



See QR Code for Proof of concept video







The testing process of this experiment showed that the humidity catching part of the strategy is easily achievable. A filtering layer has to be added up in order to be able to transfer the water from outside layers to the inside of the experiment. In

the next experiment, I check if GAC and ion exchange filters are able to clean up contaminated water. If successful, the addition of those filters to this catching mesh, will be a promising first step to the success of this strategy.

5. Nuclear Rain Funnel Level _ C

BASIC PRINCIPLES

- Filtering rain water
- Clean water storage for distribution

GOAL AND FUNCTIONING

Using a matrix of waterproof PTFE funnels nuclear rain is directed towards an active filter containing granulated activated carbon and a layer of ion exchange resin destined to the elimination of radioactive particulates coming from the rain. The weight of the water makes the funnel descend up to a level where the pioneers can remove the water for domestic use.

RADIOACTIVE DECAY TYPE

The types of radioactive decays tackled with this affirmative strategy are α, β particles suspended or adhered to matter (ash, sand, dust...) that fall when precipitations happen.

INTERACTION NATURE

This strategy focuses in filtrating interactions.

★ MEDIUM OF OPERATION

Apparatus destined for water precipitations.

ENERGY PRODUCTION

A layer of printed solar cells in the exposed side of the PTFE funnels produce electric energy.

ASSEMBLY/ DISASSEMBLY

The PTFE funnels are assembled with machine aid and since they are hydrophobic, they do not need primary maintenance. However, the water filters, are removable in order to avoid fouling and malfunctioning: they need to be decontaminated.

*** VISUALIZATION**

Water filters are coated with scintillating paint that allows the visualization of the radioactive contamination when filters are saturated with particulates.

SKETCHED ALTERNATIVES

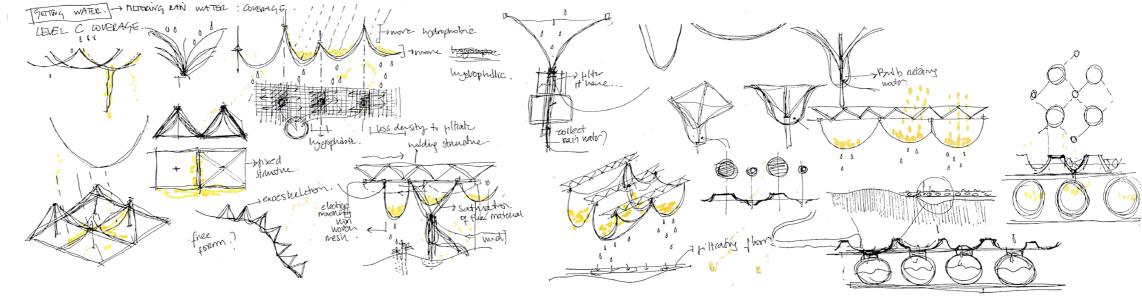
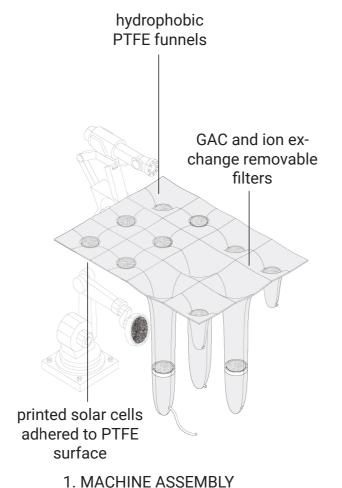


Figure 48. Nuclear rain funnel experiment process sketches (own work)

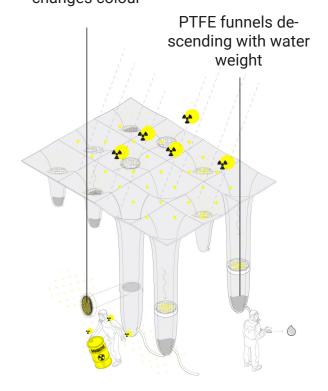
CONSTRUCTION & MATERIALITY



pipes for clean water storaged removal and domesfiltered tic use distribution water

2. CLEAN WATER HARVEST

filter removal for decontamination when scintillator paint changes colour



3. FILTER REMOVAL TO FURTHER **DECONTAMINATION**

Figure 49. Nuclear rain funnel construction process drawings (own work).

7.2 TECHNOLOGICAL TRANSLATIONS EXP 5

5. Nuclear Rain Funnel Level _ C

CHOICE JUSTIFICATION

The sketching process began by providing solutions that only attended the principle of water filtration with a bag-looking filtering system hanging off a roof structure. The main problem was that I needed to add a separate method to collect the rain, and it did not seem efficient. Therefore, the chosen alternative was to include the filtering

and the storage strategies under the same instrument. The chosen form was inspired by pitcher plants and their liquid storage, with an additional filter in order to remove radiation basic units from the rain.

Finally, instead of doing just one rain funnel, I decided to go for a matrix solution, in order to avoid oversizing of structures due to an excesive water weight.

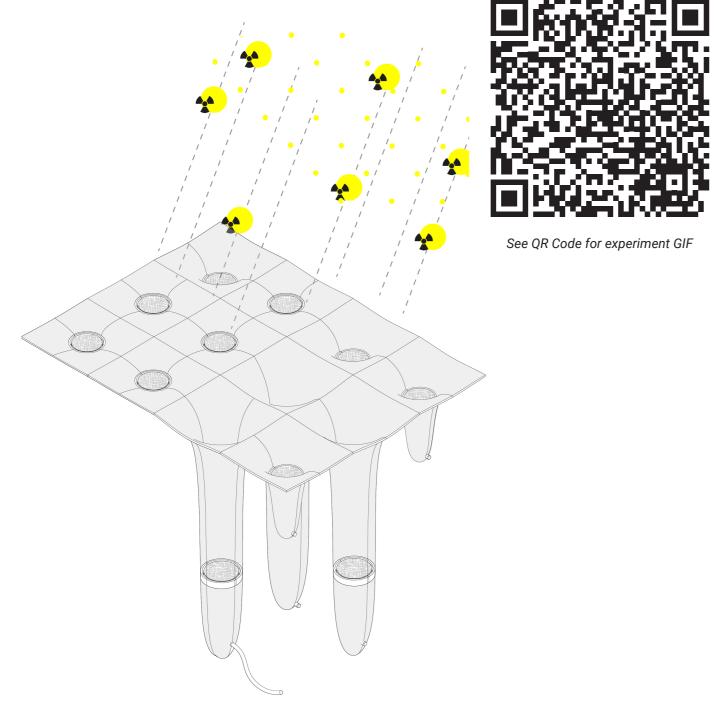


Figure 50. Nuclear rain funnel theoretical operation GIF (own work).

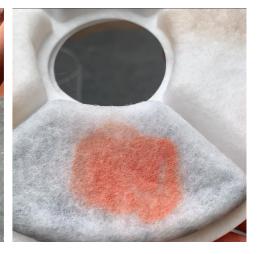
♥ PROOF OF CONCEPT VIDEO



See QR Code for Proof of concept video







The proof of concept of this experiment shows promising behaviour. The layering of a GAC and ion exchange filter absorbs a significant amount of chalk dust particles that are present in the water. I suggest that for a better purification, the

water should be filtered multiple times, and add more filtering layers. This filtering strategy can be used as well in the previous experiment, the radiohumidity harvester, to filter atmospheric water.

6. Hyperaccumulating Pads Level _ C

BASIC PRINCIPLES

- Absorption of contaminants present in soil
- Retention of migrating radionuclides
- Visualization of radiation intensity in the soil

GOAL AND FUNCTIONING

This landscaping strategy makes use of hyperaccumulators present in nature that absorb and retain contaminants present in the soil, process that is called phytoremediation.

The strategy uses a demron shielding pad (to stop radionuclides from migrating) with holes to plant the hyperaccumulators that will extract the contaminants from the soil.

RADIOACTIVE DECAY TYPE

The types of radioactive decays tackled with this affirmative strategy are α , β particles present in contaminated soils.

***** INTERACTION NATURE

Filtering and Shielding. The hyperaccumulators absorb the contaminants and the Demron pad shields the soil to diminish the migration of radioactive particles.

★ MEDIUM OF OPERATION

Apparatus destined for soil remediation.

ENERGY PRODUCTION

This strategy does not produce energy.

* ASSEMBLY/ DISASSEMBLY

The size and weight of the strategy allows for easy human manipulation. This flexible use is important to locate the demron pads wherever is needed paying attention to the medium radioactive levels and to remove the pads to subject the hyperaccumulators to a phytomining process.

*** VISUALIZATION**

The scintillators located in each pad are inserted in the soil. These crystals glow when in contact with ionizing radiation therefore a contaminated soil will cause light emission in the scintillators allowing an easily detection of radioactivity.

SKETCHED ALTERNATIVES

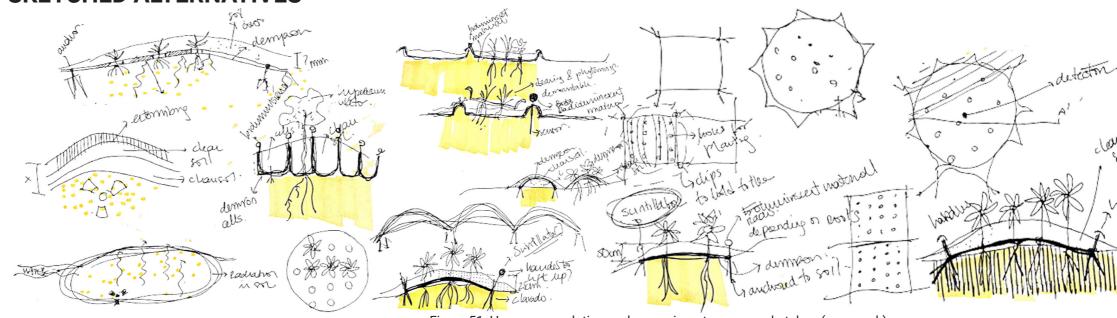
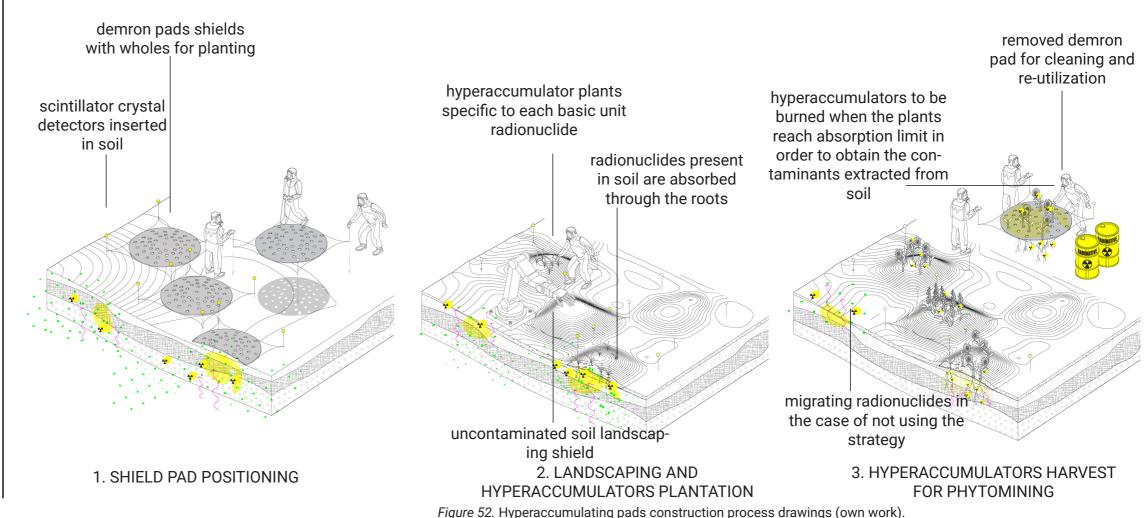


Figure 51. Hyperaccumulating pads experiment process sketches (own work).

CONSTRUCTION & MATERIALITY



6. Hyperaccumulating Pads Level _ C

CHOICE JUSTIFICATION

During the studies realized to understand how to manage the threat of radioactivity, I came across the use of hyperaccumulators for soil remediation. Plants have an specific radionuclide that they can collect and an absorption rate, so I chose the most effective ones. Another important fact of this strategy is the stopping of the migration of radioactivity and the removal of the hyperaccumulators to be burned so that is why I decided to use independent demron pads that could be located where needed in the medium and easily removed to tear away the hyperaccumulators. Finally, the choice of using scintillator markers in each corner makes it possible to visualize the ra-

diation levels present in the soil, and the securing of the pads to the ground.

Recent findings regarding shielding materials for radiation have proved that the use of a radiotrophic fungi, Cladosporium sphaerospermum, can stop the mitigation of soil radiation therefore, I am proposing the use of this eukaryotic organism as well as a more sustainable alternative to conduct the landscaping strategies of the project.

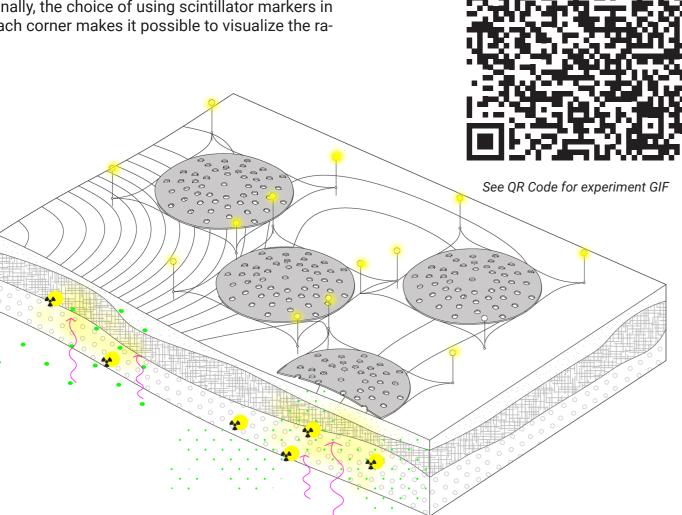


Figure 53. Hyperaccumulating pads theoretical operation GIF (own work).

RADIATION ABSORPTION RATE

The hyperaccumulating pads strategy is composed by a DEMRON shield pad and a biological component: the hyperaccumulators.

The shielding thickness of DEMRON has been calculated above in the Solar Shields experiment, so I am going to use the same thickness to achieve a similar block of radiation.

Since hyperaccumulators have specific radionuclides that they can absorb, I am choosing below a set of plants for each basic unit found in the scenario that possess the best absorption rate.

From the radionuclides, Radon-222 and lodine-131 have not been consider for phytoremediation due to the first one being a gas and the latter one having a half-life of 8 days.

The accumulation rates¹⁵ are expressed in Bq per Kg of dry weight. Bq stands for Becquerel, the activity of a quantity of radioactive material in which one nucleus decays per second.¹⁶

For the hyperaccumulators of Pu-239, there is no information about the accumulating rates.

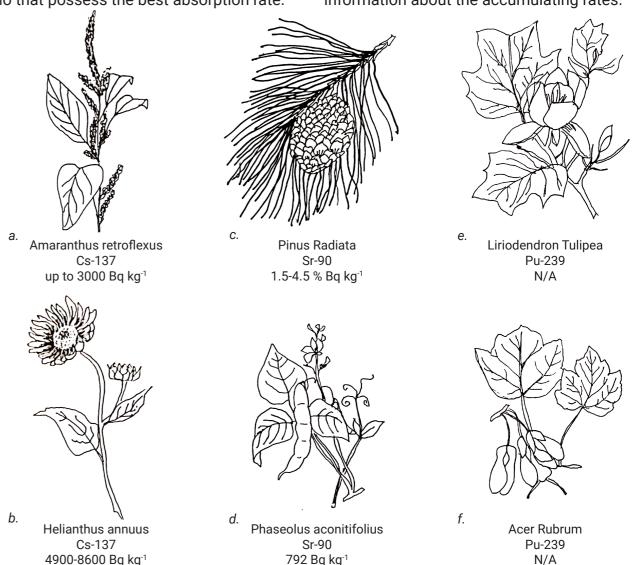


Figure 54 (a,b,c,d,e,f). Hyperaccumulator examples and accumulation rates (own work).

- 15 Wikipedia contributors. (2021, May 7). Hyperaccumulators table 3.
- 16 Course | edX. (2021). [Slides]. Understanding Nuclear Energy.

7.3 ARCHITECTURAL TRANSLATIONS EXPERIMENT OVERVIEW

TAXONOMY OF RESULTS

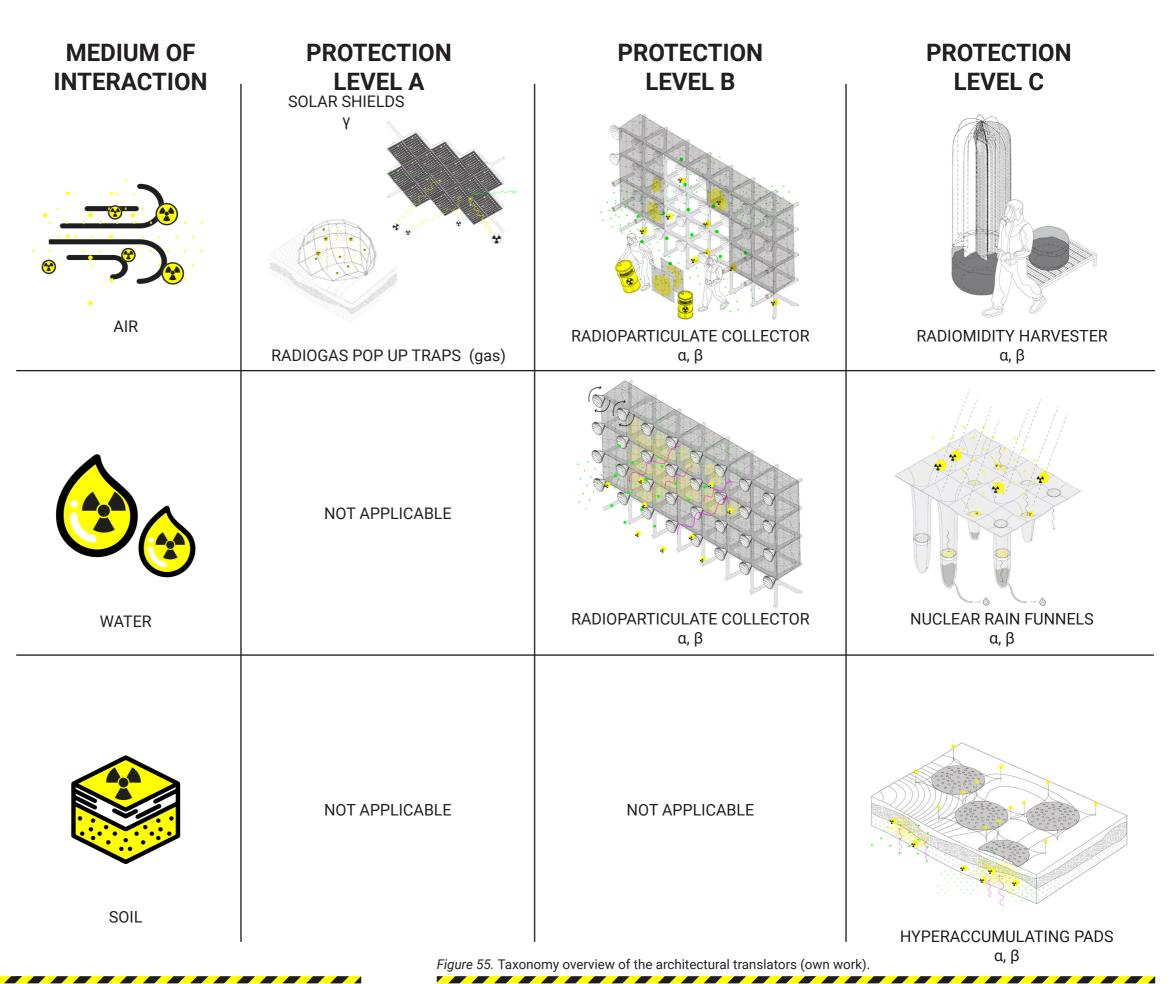
As mentioned at the beginning of the section, the goal of the experiment design is to provide an architectural language to existing technologies used against the radiation hazard.

As a designer, this exercise has proved to be crucial for the development of the project, since it has allowed me to identify the variety of forms in which radioactivity can interfere with living systems and to provide architectural responses to it.

The taxonomy of results shows an organized overview of the technological translations explored for each medium, the level of protection that they grant and the type of radioactive decay tackled.

It is worth mentioning that in the protection levels established in the Radiation Shielding Protective Clothing (RSPC) a level D is described, in which there is no hazard present and therefore there is no need to wear any shielding garnets. Due to the fact that within the scenario created for this project the radioactive threat does exist and it is mutable for the current time, there will be always need for some sort of protection (A,B or C) until the radionuclides with the longest decaying time cease their activity. This feature has resulted in the absence of any level D protection experiment during the research.

Within the focus of the technological translations to provide the possibility of creation of sheltered spaces for the pioneers inhabiting the hostile radioactive environment, the biggest effort has been invested in providing strategies for aerial protection to obtain a breathable atmosphere and body protection from different radioactivity forms (radioactive gases and decay types). Then, the experiments have been focused in the collection of clean uncontaminated water for daily activities and finally in the remediation of the soil that will allow the resumption of life in it.



B. CONCLUSION

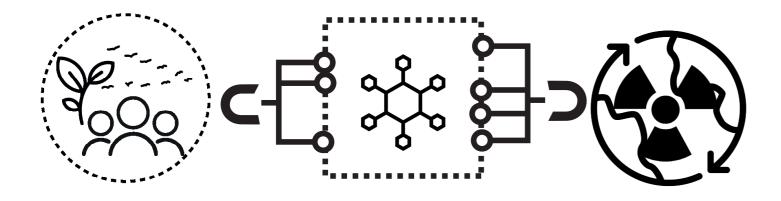
What can be established from this research is that there are existing technologies being currently used in disciplines regarding nuclear energy and ionizing radiation which can be translated to the architectural field. As designers, we play a crucial role in what kind of spaces are created from the adaptation of these technical strategies.

The main goal set for this graduation project was to restore and reinvent, through Architecture, a broken bond between the living systems and the geophysical environment after the event of a radioactivity release. While architectural responses to nuclear hazards are existent (bunkers), I believe these are negative solutions: they accentuate the secrecy around the topic and they are presented as a selfish anthropocentric approach, leaving the geophysical environment and rest of the living systems out of their "protection bubble" and therefore, not tackling the hazard at all.

This research has focused in the knowledge gap that exists currently in Architecture in relation to radioactivity. The gap of exploring innovative and imaginative uses of technologies from different disciplines to provide and create a set of affirmative design responses that embrace the problem of radiation, instead of neglecting it.

The affirmative architectural solutions proposed in this research succeed in referring to the different components defined in the hierarchical scheme at the beginning of the paper that aimed to identify the conflictive points between the two domains of radiation and the living systems. And, from the overview of the experiment results, it can be appreciated that the kind of Architecture that can come out of the research focuses in the exposure of the hazard of radioactivity and a transparent use of the technologies that allow a non-detrimental interaction with radioactive environments. The aesthetic impression of this type of Architecture will be then strongly influenced by the functioning of these technological translations.

A new relationship between the living systems and the geophysical environment can be now established, through the variety of architectural translating strategies developed during this research that accept the constant presence of radioactivity and puts the inhabitants of the scenario in a position of extreme cohabitation with the hazard.



9. DISCUSSION

When I chose radiation as a topic for my graduation studio, I was aware that it was going to be a challenging project. Not only due to the knowledge I do not possess because of the choice of my career and the confidentiality of the information around the topic, but also for the challenge of convincing my tutors and others about the feasibility of a project like this one.

As a personal reflection, I would like to start by stressing out again the lack of information and the secrecy around the topic, when it is a hazard that has one of the biggest environmental consequences existing on Earth. In fact, this secrecy has impacted the development of the paper since the private nature of new researches around materiality and technological advances to palliate nuclear disasters has made it difficult to fully grasp and understand the innovations that are being currently studied.

It is disappointing as well, that when trying to reach for help from professionals in the topic, even within the academia environment there was no two-way communication at all, revealing again the mysterious halo that surrounds the nuclear related disciplines.

Moreover, due to the fact that radiation related activities involve a great threat, I have found the materialization of the physical experiments the biggest limitation. However, with the resources that I have been able to find, and by exploring valid abstractions of how radiation can be represented, I have worked out a way of developing the research based on experimental design.

This methodology, I believe it has helped me to get a visual and a more tangible grasp of the topic and has facilitated the connection between the research and the design. In a retroactive way, the experiments have provided a set of foundations in which the design can rest on due to the fact that they have created the opportunity to evaluate and give an architectural twist to existing technical strategies used to tackle radiation in other disciplines. And the other way around, the design intention of the project has helped in framing the

technical strategies considered for the research, only including the ones that could have an architectural translation.

In regards to future research about the topic, I wish there could be more access to safe testing grounds (even simulation modelling) or a more reachable path to obtain information and material samples. I believe as well that a cross-disciplinary collaborative approach would be definitely valuable if investigations about inhospitable environments want to be developed further.

Concerning the relation between the building environment and radiation, there are existing typologies that claim to solve the hazard, as mentioned in the conclusion, that however, are obsolete and incomplete. There is an increasing tendency in the use of nuclear resources to respond to the ever growing societal energetic needs, and therefore there is an urgent demand of researching alternative architectural solutions that can provide a valuable response in case of a nuclear accident or even to manage the radioactive debris originated from these activities since they have a direct impact on all living systems and the geophysical environment.

As a whole, this research explores a controversial recurrent topic from an architectural perspective with the intention of opening cross-disciplinary discussions regarding the impact of our ways of living and our relation to the usage of resources of our planet, in an speculative manner.

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SCENARIO STORY NOTES. A REALITY WE MIGHT LIVE TO SEE

The scenario built for this graduation project is based on real facts adapted to a fiction story. I have combined within this page notes related to relevant parts of the storyboard. Each note corresponds to the same numbered illustration.

that's made to withstand war with North Korea. (2017, May 5). Business Insider. https://www.businessinsider.com/north-korea-nuclear-war-bunker-japan-photos-2017-5?international=true&r=US&IR=T#shelter-cos-model-bunker-is-located-inside-the-home-of-the-companys-ceo-seiichiro-nishimoto-in-osaka-japan-1

Note 1

The Paris agreement bonded 196 countries to set long-term goals regarding the reduction of greenhouse gas emissions to maintain the global temperature rise below 1.5 degrees Celsius.

Source: United Nations. (2015). The Paris Agreement. https://www.un.org/en/climatechange/paris-agreement

Note 2

France has just announce his vow to building more nuclear power plants. Precisely, the President said that they plan on building six more nuclear reactors. The reason behind this choice is to keep the energy prices low and to gain energetic independence in the country. Also, to reach the carbon neutrality goal by 2050.

Source: Reuters. (2021, November 9). Macron says France will build new nuclear energy reactors. https://www.reuters.com/business/energy/macron-says-france-will-build-morenuclear-energy-reactors-2021-11-09/

Note 3

France has already 56 nuclear power plants in operation.

Source: Reuters. (2021, November 9). Macron says France will build new nuclear energy reactors. https://www.reuters.com/business/energy/macron-says-france-will-build-morenuclear-energy-reactors-2021-11-09/

Note 5

In Japan, sales of custom made bunkers for nuclear shelters are increasing. They are actually building them to respond to a natural disaster, terrorist attacks or catastrophes. The bunkers are fully equipped and "beautifully" decorated.

Source: Inside an underground nuclear bunker in Japan

Note 9

The hour and date of the event is the same as the Chernobyl accident, 70 years ahead.

Source: Greenspan, J. (2019, July 21). Chernobyl Timeline: How a Nuclear Accident Escalated to a Historic Disaster. HISTORY. https://www.history.com/news/chernobyl-disaster-timeline

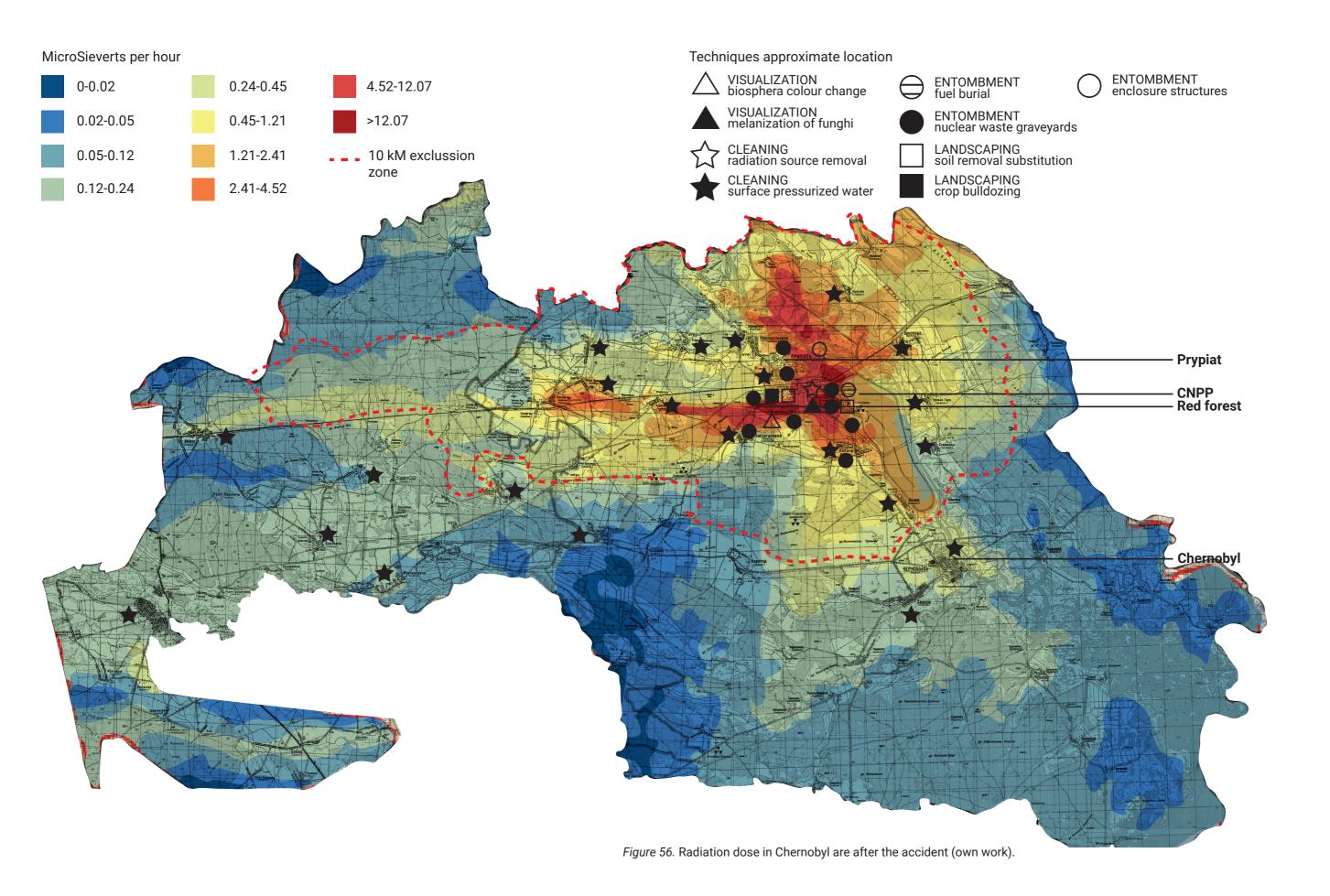
Note 11

The contaminants chosen for this scenario are the ones released after the Chernobyl accident.

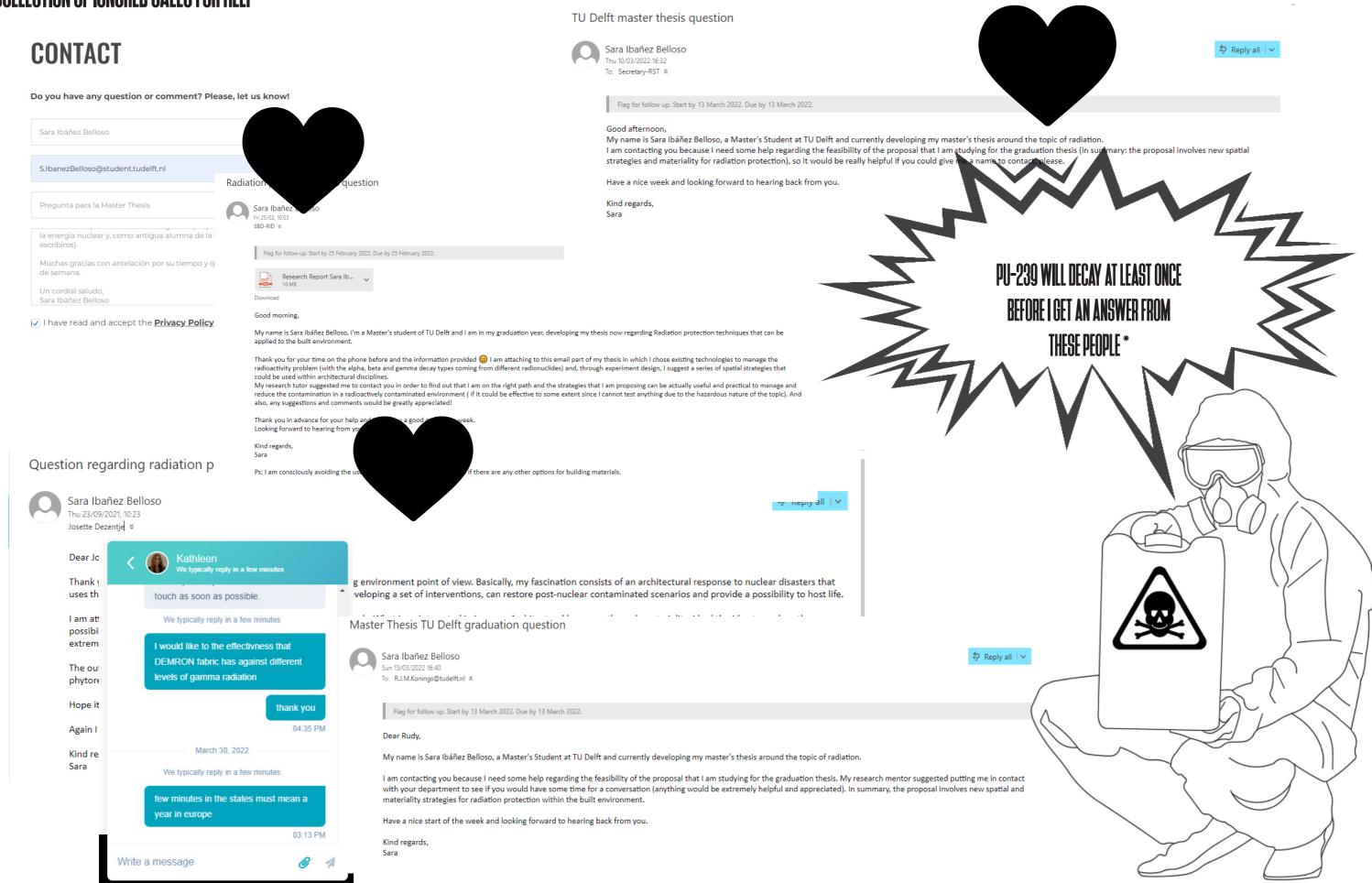
Source: Environmental contamination and other consequences of the Chernobyl reactor accident. (n.d.). Federal Office for Radiation Protection. https://www.bfs.de/EN/topics/ion/accident-management/emergency/chernobyl/environmental-consequences.html#:%7E:text=The%20accident%20at%20the%20Chernobyl,the%20environment%20are%20still%20exposed.

apan 68

CHERNOBYL RADIATION DOSE MAP



COLLECTION OF IGNORED CALLS FOR HELP



OPPENDIAPERSONAL REFLECTION

Prior to the start of this academic year, when conducting the interview to participate in the 'Explore Lab' Graduation studio, I challenged myself to tackle, through the power of architectural imagination, the ever-present potentiality of a dystopic event: a nuclear disaster that would change life as we currently know it on our planet. The graduation project of 'Inhabiting the inhabitable: Post-Nuclear Cofrentes, 2056', narrates an evolutionary exploration of unconventional ways of living in a post-apocalyptic scenario where radioactivity has obliterated any hopes for humanity's future on the surface of the Earth.

The research phase of the graduation studio focused on providing architectural translations to radiation-management technologies that already exist within disciplines related to nuclear physics but whose potential has not been fully exploited yet, as well as creating the necessary architectural systems to make them work together holistically in a real-life setting. The fact that this investigation has mainly been carried out through the methodology of research by design has been crucial for the successful transition from the research part of the project to the design phase. In addition, this methodology provided the project with clear architectural aesthetics from the outset. Furthermore, even if the secrecy and the lack of available information around the topic demanded a reframing of the study to only using techniques that could be adapted to the built environment, such obstacles made the development of the research, along with its subsequent results more tangible and applicable. The question that had to be answered was the following: what kind of architecture can emerge from the researched technologies to fit within the scenario?

The first approach to the design consisted of a three-week-long study of three different precedents that provided useful knowledge necessary to tackle the challenges of the design process. The three projects had different locations, levels of detailing, and degrees of speculation. After these precedent studies, I continued with an extensive site analysis of my location of choice, which further strengthened the decision I made

for the P2 to focus on the town of Cofrentes and its surroundings. I am grateful to have taken the time to do this as it gave what originally was an intuitive decision a very strong logical foundation that fully justifies my choice.

Simultaneously, and in order to ground the project, I was suggested to seek experts' advice about the viability of the outcomes found in the research and to see if they would truly work when applied to the built environment. Unfortunately, the search for help was in vain since no email was responded and no phone calls were returned. This lack of assistance, together with the feedback received on the P3 from my mentor team, lead me to engage in a thorough reexamination of the project, which I saw as an opportunity to enrich my work with a more humane and playful touch that would not only make me enjoy the design process more but also to propose a much more complex and nuanced project.

Even though initially the feedback received at the P3 caused me stress, when I reflected on it, I was grateful. Without it, the project would have been overcontrolled and lifeless so the decision to start over with the comments from the mentors and the lack of help from experts in the topic granted a new strength to the narrative.

If I am honest with myself, one of the main difficulties that I have faced and from which I have learned considerably during this graduation year is the tendency to overcontrol situations, an attitude that in the beginning seemed logical and justified due to the nature of the project but that, when looked from other perspectives, became completely unrealistic and inhumane. This led to situations like on the P1 and the P3, in which the work I showed and the ideas I proposed did not reflect my personality as an Architect. It is thanks to the 'wake-up calls' from my mentors that I was able to overcome these difficulties!

Concerning the relation between the research and the design, the paths I explored within the first half of this graduation studio, together with their outcomes, proved to be crucial for the satisfactory development of the project. Without proper knowledge of the fundamentals of radioactivity and without conducting research by

design to establish a relation between technical strategies used in nuclear disciplines and architecture, I believe I would have been lost in the complexity and obscurity of the topic.

The selection of this topic was born out of pure fascination, which was the main reason to choose the 'Explore Lab' graduation studio to develop this project. The studio has an individual structure that allows you to focus on the aspects that personally interest you the most. In my case, and in relation to the Architectural Master Track, my fascination lies in the role of the architect as a storyteller that has the power to plant speculative seeds and inspire new ways of living for the future.

When I look back to the beginning of this radioactive exploration project, I never expected to find a definitive solution to a problem that has been present in our societies for over one hundred years, raising fears and worries. I am definitely not an expert in the topic of radiation and a lot of knowledge goes beyond my scope. However, I do believe in the power of architectural imagination. Speculative projects like this one can trigger those who see them to reconsider their everyday habits, cultivate social and environmental values, and raise awareness towards the usage of the resources of our planet.

'Inhabiting the inhabitable: Post-Nuclear Cofrentes, 2056' tries, as well, to add transparency and tangibility to the invisible hazard of radiation which is, still, a topic of contention, and is carried with extreme secrecy, even in Academia. The goal of this project is not to force a position regarding the usage of nuclear energy, but to expose a future that accidents such as Chernobyl or Fukushima have proven to be a reality that we might live to see.

