PHOSPHORESCENCE TECHNOLOGY FOR TOILET LIGHTING IN REFUGEE CAMPS

PHLUÒ

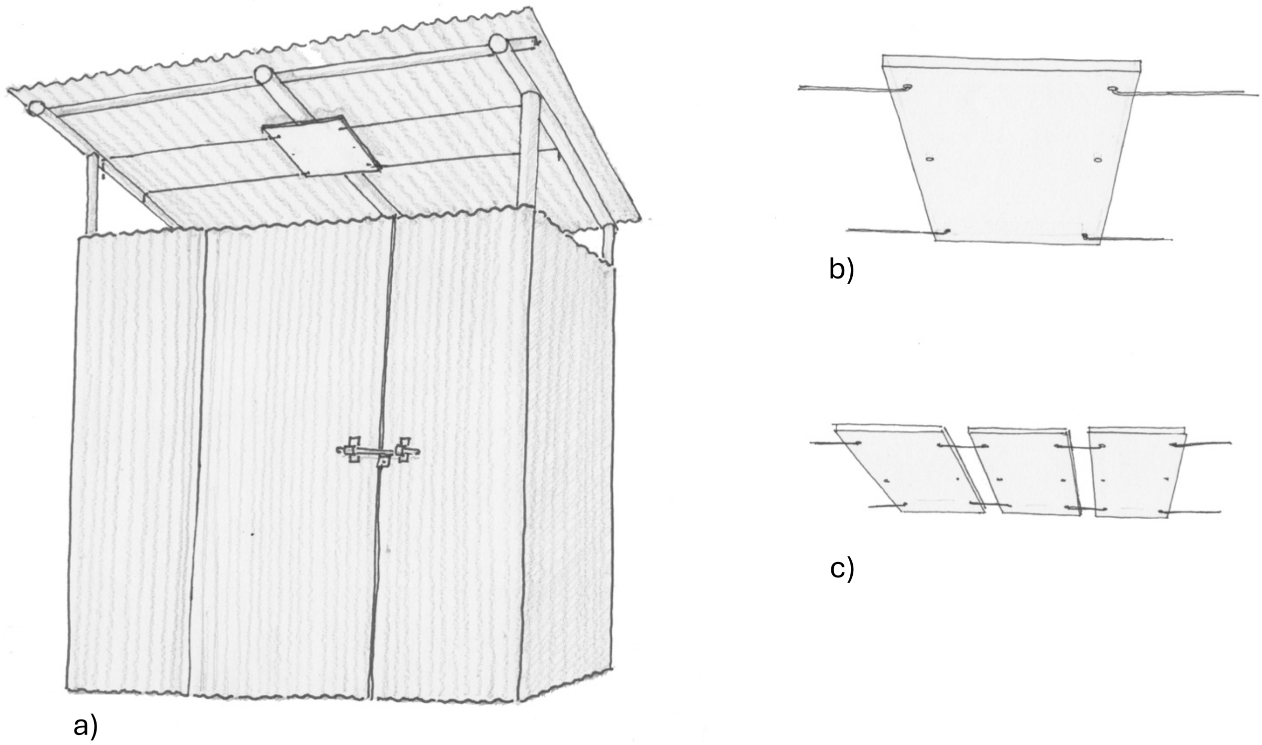
DESCRIPTION FOR THE PROPOSED NEW LAMP

Problem & Opportunity

The prototype is a modular resin panel suspended from a steel chain (or similar material) or fixed directly to the surface with simple nails. This freedom of fixing gives the panel great flexibility of use.

The panel, designed especially for latrines, thanks to its modularity can also be adapted to larger spaces by adding modules (panels) on the same chain (Figure 1) or by increasing the percentage of phosphorescent pigment in the mixture.

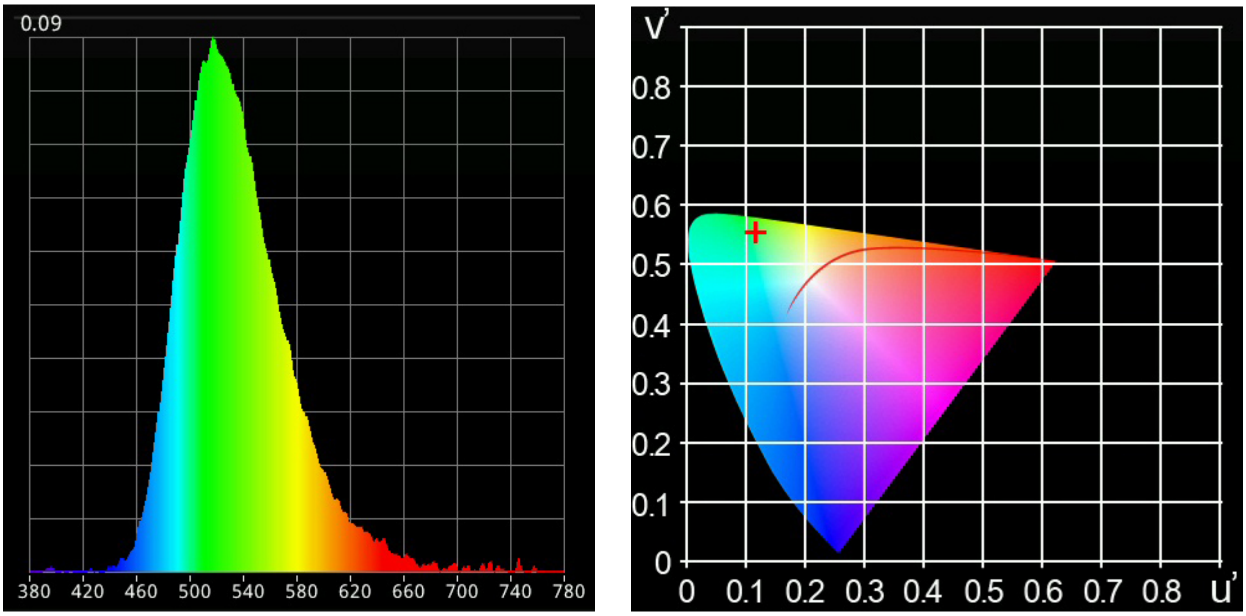
The chain also acts as a guide on which the panel itself can slide, allowing the light to be more concentrated in particular points of the latrine or in larger spaces.



a) b) c)

Figure 1. a) Installation sketch of the panel in a typical latrine. The little chains that support the structure are visible. b) A small chain can pass through the panel to secure it. The chain passes through the holes which could also be used to nail the direct panel to the structure c) A small chain can pass through the panel to secure it. The chain passes through the holes which could also be used to nail the direct panel to the structure. *Drawing by the solver*

A light-green phosphorescent pigment was chosen as light source because, compared to other colors and with equal material, its spectral luminous component emits a greater amount of light. (Figure 2) This allows a certain saving of material. This aqua green light also lends a pleasant decorative effect. In fact, during the design phase we tried to create an object that, in addition to illuminating, would also give greater grace to the latrines.



a) b)

Figure 2. Spectral results after testing the glow panel. a) Spectral curve b) CIE1976 chromaticity (u', v') values. *Images obtained through the spectrometer used for panel measurements*

The panel can be nailed close to the ceiling (in latrines with low ceilings) or it can be suspended slightly below the ceiling surface via the little chain. In this latter case, since the panel emits light from both sides (actually doubling the luminous surface), it would also illuminate a part of the metal sheet ceiling and thus, through the light reflected by it, it would contribute to illuminating the ground. The phosphorescent mixture would therefore be almost completely exploited, avoiding the waste of light that would occur in panels or lamps with a blind bottom. Finally, a lit ceiling helps to balance the luminances within the environment which favor a better perception of the space.

Unlike a phosphorescent paint applied on a rigid structure (metal, wooden panels), the advantage in using diffusing resin panels is the possibility of increasing or decreasing the quantity of phosphorescent pigment inside the mixture to increase or reduce the amount of emitted light and be able to adapt the panel to different types of environments.

The resin, with which the panel is built, is a material that suits well the latrines because it is a monolithic surface, without cracks or grout lines which avoids the accumulation of dirt and dust and does not allow the absorption of any liquid and is easily cleanable (with a cloth or water hose). Furthermore, the resin surface is not prolific for fungi and bacteria making it perfectly suitable for use in health and hygienic structures such as latrines.

Another characteristic of the resin is its insensitivity to UV light radiation and bad weather. This prevents:
- a yellowing of the material over time and a consequent opaqueness of the structure (as

happens, for example, with plastic materials). The brightness therefore remains unvaried over time.
- an oxidation of the material. Using other materials such as metal sheets the structure could rust and the phosphorescent material detach.

Solution Overview

Brightness checks were conducted considering a charging period of 8 hours and a glow one of 12 hours (See videos). Even after 4 hours recharge, the glow period lasted for about 3 hours (the only measure taken in this case). This suggests that it will be possible to recharge the panel even in less time (than 8 hours). The light is enough to read a sheet (14,5 points) in the first 4 hours. (Figure 3)

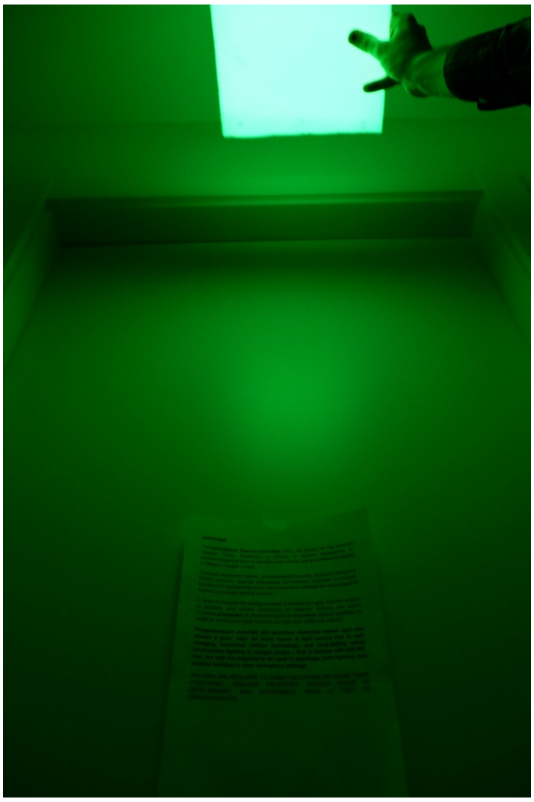


Figure 3. Image of the panel positioned at 2,25 m high after a period of one hour of darkness. The written paper sheet was glued to the wall at approximately 1,4 m

The panel is made of resin into which a phosphorescent powder is mixed (24% of its volume). The powder (grain size around 85µm) is composed of 95% Strontium Aluminate (Mr 205,58) doped with Europium and Dysprosium ($SrAl_2O_4:Eu^{3+},Dy^{3+}$).

The panel has small dimensions (25 cm x 25 cm x 0.5 cm) and low weight (0,520 kg); this facilitate transport and installation in almost any space such as in latrines or near windows with small openings (without obstructing the view or the air flow).
The panel, if installed with the chain, can slide manually back and forth in the space in order to concentrate the light where you want it. If necessary, the panel can also be secured to the structure (walls or ceiling) with simple screws or nails.

It is easy to manufacture anywhere and by non-specialized individuals. Through a mold, hundreds of panels can be produced even in the same camps (Figure 4).

The panel material is non-toxic and is not hazardous waste; it can be recycled at the end of its life.

Figure 4. Photographs showing the preparation of the first mould. The manufacturing was deliberately carried out with simple tools and not in a laboratory to demonstrate that the construction process can be done anywhere and by people with no experience. The polystyrene was cut with a blade.

Experience

My professional lighting design studio, based in Milan (Italy) and Barcelona (Spain), has been involved in lighting design for over 10 years in various fields: from churches (e.g. the Cathedral of Milan), to museums (e.g. Palazzo Grassi), to infrastructure (e.g. Malpensa Airport), to art exhibitions, to the redevelopment of public areas, to domestic environments or to natural or artificial lighting consulting. The studio sometimes also deals with the design of custom-made devices from the idea to certification (e.g. UL). Alongside the design activity, my studio also carries out research activities; I am indeed interested in technological and scientific innovations regarding different light sources (both natural and artificial) because this falls within my interests and training activities.

I am part of a group of the Italian division of the CIE committee (which deals with the drafting of European standards on lighting) and of various lighting associations such as, for example, IES (USA) which are especially involved in research in the scientific and regulatory field.

I believe the light is a tool to improve the quality of life for all people in whatever condition they find themselves. For this reason, I am convinced that studies and paths must be undertaken that lead to the development of technologies that make light a universal good accessible to all and in respect of the environment. With my studio, I would therefore be very interested in starting a collaboration with IRC because I believe that lighting should not just be relegated to large works but is a means to improve the quality of life of people and the realization of lamps to be used in refugee camps exemplifies this will.

I find the possibility of working on the design of autonomous lamps (for example with phosphorescence) very interesting because it is a sector that would greatly contribute to the reduction of pollution generated by artificial supplies of electricity. Through my studio, I would therefore make available to IRC all my knowledge and skills in lighting (from the design of spaces, to the study of new solutions, to the certifications of any devices or scientific measurements in the field) to improve as much as possible the conditions of the people who live and work in the camps, both from the point of view of their psychophysical well-being and their safety.

Solution Risks

The weak point of the solution is a slight fragility of one of the fixing methods. By applying a lot of force, the chain could be torn and the plate removed. However, it is possible to reduce the risk of vandalism by nailing the panel directly to the structure (roof or wall) through one of its holes. However, by doing so, one of the two luminous faces of the panel would be obscured; alternatively, the panel could be nailed to brackets or beams below the roof.

Timeline, capability, and costs

The proposed solution is easily implementable anywhere, including refugee camps, and does not require special knowledge or skills. The raw materials, with which the panel is constructed, can be easily sourced through numerous distributors accessible via internet. The panel is made of a strong clear resin to which phosphorescent powder is immersed. To construct the panel, it is therefore advisable to first manufacture a silicone mold (costing about $1.5) that can be used for the serial production of the panels. The silicone mold can, if necessary, be replaced by a formwork made with different, more convenient or locally available materials. A single silicone mold allows in any case to produce hundreds of panels and its cost would be amortized after the fourth (a maximum expense of $5 / panel was considered). The costs above-mentioned and reported in the attached BOM, are to be understood, in the face of a purchase of large quantities of raw materials, as the final cost of a panel within a production of various elements. A peculiarity of this project is indeed the modularity of the system. The proposed solution is designed as a system, composed of modular panels, capable of being implemented and adapting to environments with different functions and dimensions. In case of need, each individual panel must also be able to be replaced and manufactured quickly and the possibility of having a mold significantly reduces production times. The lamps would thus be produced in series covering the great demand for light in refugee camps not only inside latrines but also in tents, shelters, common meeting areas. The panels could therefore be declined in a family of lamps to be used throughout the camp.

The panel, being very simple to construct, could also be made in refugee camps or by people with little experience.

All the components to make the panels (resin, and phosphorescent powder) can be stored in warehouses inside the refugee camps or at the IRC headquarters, eliminating the waiting times for supplies. In addition, the finished panels, thanks to their reduced dimensions, can be tied together, stacked and stored in large quantities so as to always have new panels available when needed. Taking into account the manufacturers' data (from whom I purchased the materials for the prototype realization), the panel has an average lifespan (luminous) of about 30 years. However, this data can vary depending on the manufacturer or the mixture.

The production of a working panel (TRLs 7-8) requires about 24 hours of time at 15-20°C. Higher temperatures, which are easily found in tropical areas, reduce the solidification time of the material. The overall cost of a panel is about $4.5 (see attached BOM for more details).

The production phases are divided as follows:
- Realization of the formwork (unique for all panels). Time: 20 hours. Cost: about $1.5
- Preparation of the phosphorescent resin mixture. Time: 30 minutes. Cost: about $5
- Pouring of the resin inside the mold. Time: 30 seconds
- Drying of the resin. Maximum time: 24 hours

Solution Summary

The panel is suitable for use in refugee camps because it meets the health and sanitation requirements set by IRC and OCHA (“Wash Sector Nigeria” document).

Regarding the “Proof of concept”, the proposed solution is around level 7 as the prototype is fully functional and has been tested in a room whose dimensions are similar to those of a latrine (1.2-2 m x 1.05-1.5 m x h. 2-2.5 m).

Contacts have been made with several companies that produce phosphorescent material, even for large supplies.

The light spectrum in the field has been measured, as well as the illumination levels, but some technical measurements on luminance are still missing because the suitable instrument is not currently available in my studio.

During the tests, various mixtures based on Yttrium, Zinc or Calcium (such as $Y_2O_2S:Eu^{3+}$, $CaAL_2O_4:Eu^{2+},Nd^{+}$, $ZnGa_2O_4:Cr^{3+}$) were considered, but the one that convinced me the most is composed of strontium aluminate ($SrAl_2O_4:EU^{3+},Dy^{3+}$). A future collaboration with chemists who can help improve the chemical composition of the phosphorescent mixtures would also be desirable.

Online References

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- DIN 67510-2:2022-07 Photoluminescent pigments and products - Part 2: Measurement of phosphorescent products on site

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