DESIGNING A LOCALLY ACCEPTABLE SYSTEM FOR IRON SUPPLEMENTATION

BY STAYPINK (ANEMIA PREVENTION TEAM, IDDS AAROGYAM)

PROJECT TEAM

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ABSTRACT

We set out to tackle iron deficiency anemia, a health problem that was not only present in Kuthambakkam where we worked but that affected all of India, South East Asia and nearly a third of the world's population.

Further research led us to define a design goal which was to develop a locally acceptable system for iron supplementation.

Guided by our goals, we explored a few ideas but we were careful to involve the community members through a co-design process and our design goals matched their needs in "*water as a vehicle for iron supplementation.*"

This led us to the development of the H2Pink, a system for the iron fortification of drinking water in homes. Family members can get up to 40% of the required daily intake for iron without doing anything new but by just drinking water like they already do every day.

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CONTEXT

BACKGROUND

Iron Deficiency Anemia is the commonest nutritional deficiency disorder globally. It occurs when the red blood cells are unable to carry enough oxygen to the body tissues.

> *According to the World Health Organization, anemia is defined as a condition in which the hemoglobin content of blood is lower than normal as a result of deficiency of one or more essential nutrients, regardless of the cause of such deficiencies.* [1]

1.62 billion People around the world are affected, which corresponds to 24.8% of the world's population. It has been most commonly found amongst preschool-age children (47.4%), and least common amongst men (12.7%). However, the group most commonly affected is pregnant women (41.8%). Anemia may be the underlying cause of maternal and perinatal mortality.[2]

90% of anemic people live in developing countries, about 2 billion people suffer from anemia and an even larger number of people with iron deficiency. An alarming 600 million people in South-East Asia are suffering from iron deficiency anemia, predominantly affecting adolescent girls, pregnant women and preschool age children.[3]

Prevalence of anemia in all groups is higher in India as compared to other developing countries.

> *According to the National Family Health Survey (NFHS)-(III), more than half of women in India (55%) have anemia, including 39% with mild anemia, 15% with moderate anemia and 2 % with severe anemia. It is estimated that 20% to 40% of maternal deaths in India are due to anemia and one in every two Indian women (56%) suffer from some form of anemia.*

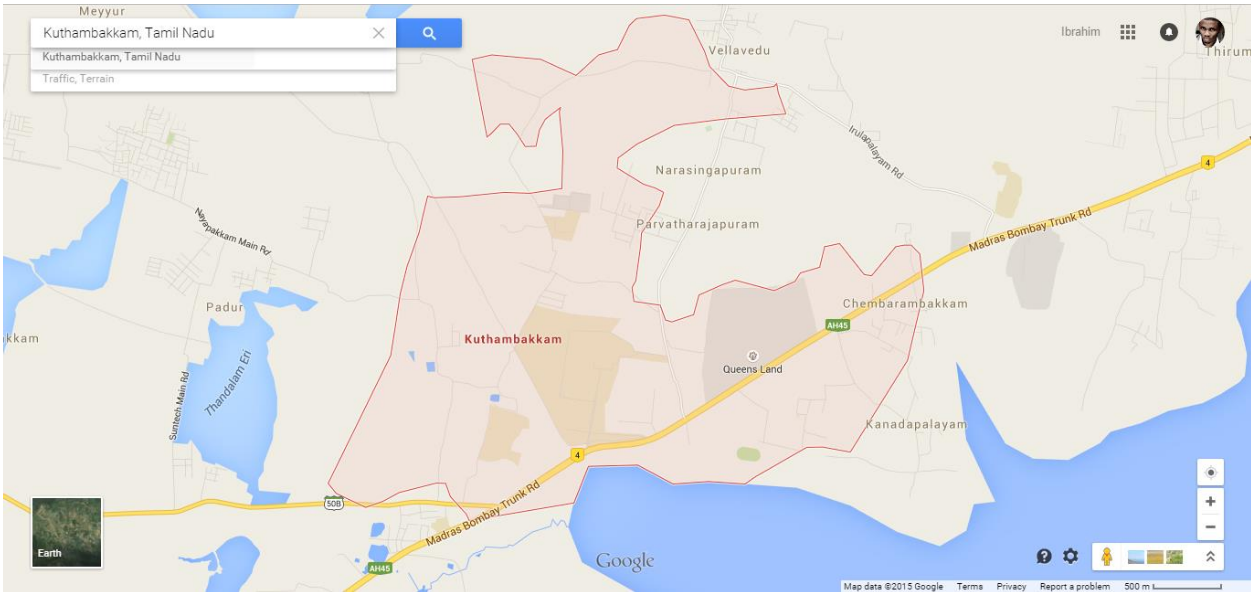
Data from the Indian Council of Medical Research and District Level Household Survey show that the prevalence of anemia is very high (ranging between 80 to 90%) in preschool children, pregnant and lactating women and adolescent girls. Low birth weight infants, young children and women of childbearing age are particularly at risk of anemia. That way Anemia begins in childhood, worsens during adolescence in girls and gets aggravated during pregnancy.[4]

The reasons for these findings range from high cost of healthcare facilities, poor food quality and the low status of women. However, the high prevalence of anemia in India is due to low dietary intake, poor iron (less than 20mg/day) and folic acid intake (less than 70 micrograms/day); poor bio-availability of iron (3-4% only) in phytate-fiber rich Indian diet; and chronic blood loss due to infection such as malaria and hookworm infestations.[4]

NOTES

1. WHO. Geneva, 1989
2. WHO, WHO global database on anemia/ Edited by Bruno de Benoist, Erin McLean, Ines Egli and Mary Cogswell, 2008. http://whqlibdoc.who.int/publications/2008/9789241596657_eng.pdf
3. I Capoor; J Gade; CHETNA Team, Paper presented at the World Congress on Women's Health on November 10th, 11th & 12th, 2000 at Science City, Calcutta, 2000.
4. Kawaljit Kaur; Anemia "a silent killer" among women in India: Present scenario. European Journal of Zoological Research, 2014, 3 (1):32-36

ABOUT KUTHAMBAKKAM VILLAGE



A Google Maps capture of the Kuthambakkam area

Kuthambakkam Village is a village in Chennai, Tamil Nadu State which is considered as a model village in India. It has a population of over 5,000 people distributed across seven hamlets within the village.

Governance in Kuthambakkam is through the village panchayat system that employs a bottom up approach (Mahatma Gandhi's philosophy of governance) between the rural people and the government. Decisions on development are made collectively by the people and their leader through meetings held periodically at the village center.

Kuthambakkam has seen a lot of transformation in the past two decades when the panchayat system was first adopted by the village and through the leadership of Mr. Elango who was the Panchayat leader for nearly a decade since 1996. During this period and beyond there were significant reduction in gender violence against women, unemployment rates, tribalism and there were development projects in partnership with the people.

The village has one village health nurse and a health sub center. Community members also have access to the Primary Healthcare Center which they share with 2 neighboring villages and within which they can be attended to by a doctor and they can also utilize laboratory services.

The Primary healthcare center and the village health nurse mainly caters for conditions of public health priority including care of pregnant women, anemia prevention programs, treatment of snake bites and dog bites etc. For emergencies and treatment of chronic conditions, the villagers utilize a private medical college (Saveetha Medical College) also located in the village.

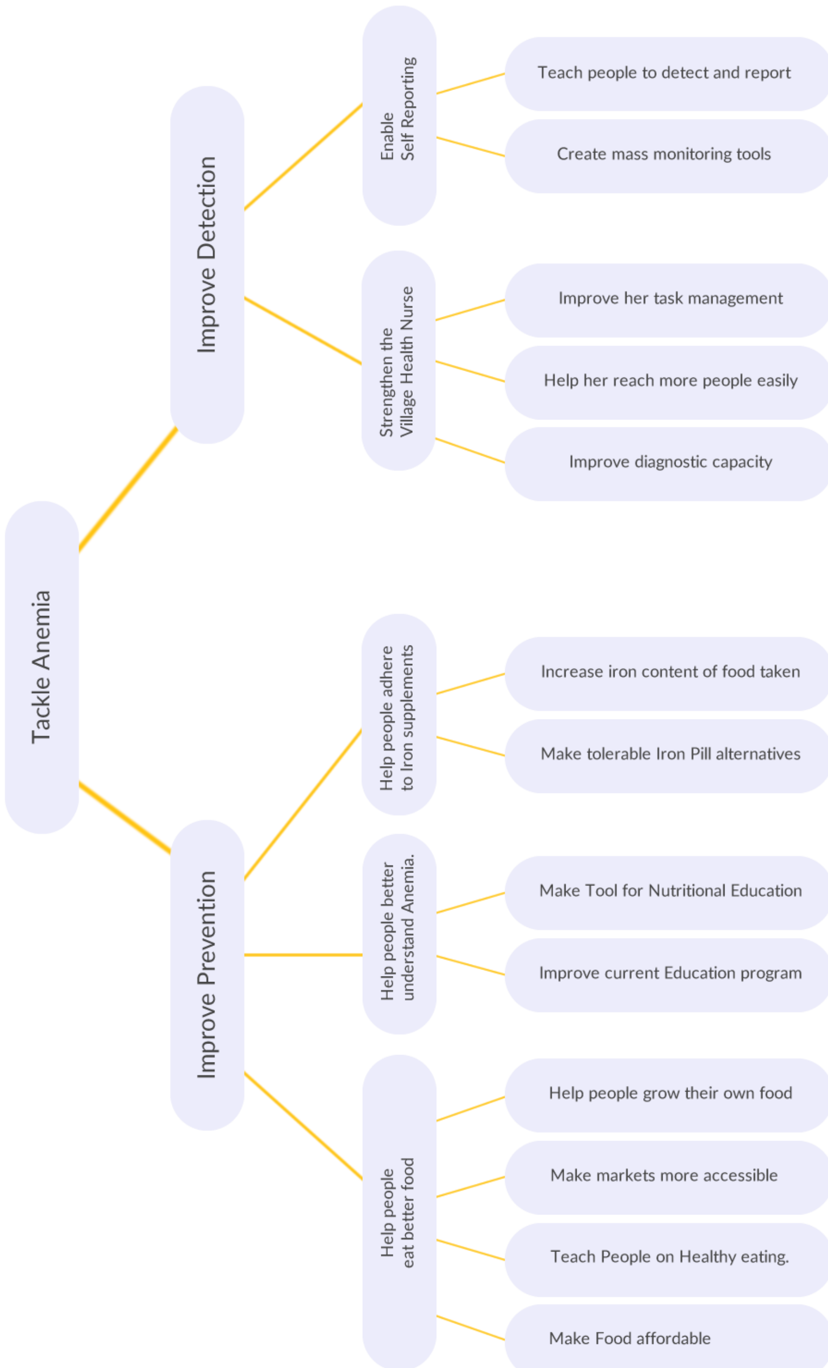
Some of the other observations from visiting Kuthambakkam were:

- The cohabitation of streets by rich and poor families;
- More than 70% of the population were low income earners (farmers, porters, washer men etc.)
- There was also strong support for living from the government. (Most of the appliances in homes including televisions, refrigerators, etc. were provided free of cost by the government.)
- There was a program to ensure 100 days of guaranteed employment for the poorest of the poor.

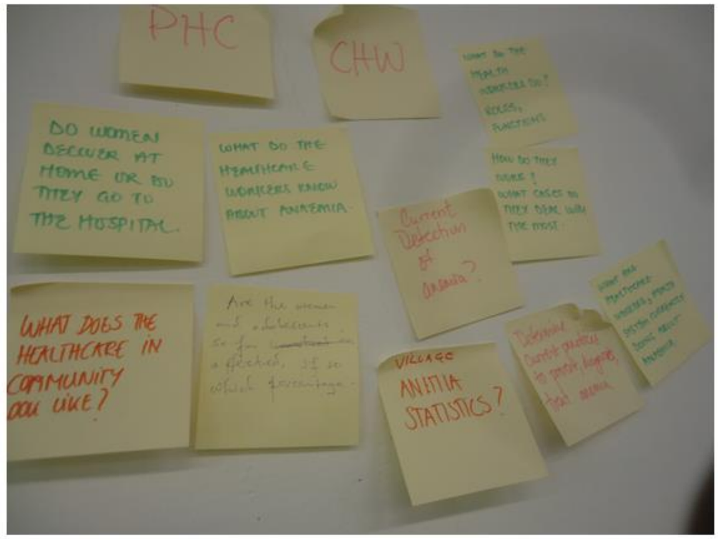
02

PROCESS

THE PROBLEM FRAMING TREE



SUMMARY OF THE DESIGN PROCESS



After receiving the broad description of the problem with anemia detection and prevention in India, we conducted further research to better define the problem. This included the details of iron deficiency anemia, its causes, the high risk groups, its implications and the fact that beyond the prevalence in India, it's a global problem affecting about 2 billion people around the world and responsible for 800,000 deaths every year.

We also studied the Indian healthcare system especially with respect to public health interventions identifying things like the priority healthcare conditions, current government programs to mitigate various health and health related problems including anemia as well as the healthcare system’s structure and its important stakeholders.

Through this, we were able to get an idea of the manner in which the public interacted with the healthcare system and it helped us conduct a preliminary stakeholder analysis and prepare questions to ask them during our community visit to better understand the problem.

So, after being empowered with some design tools, we went to the village speaking to all the different stakeholders we have identified: Families, School students, Village Panchayat Leader, Women Groups, Pregnant Women in the Primary Healthcare centers etc. We were interested in understanding

- how people perceived this problem,
- and if the different stakeholders even recognized this as a problem and
- the different strategies/approaches already being utilized to tackle this issue.

We realized that most of the families we spoke to were not necessarily aware of anemia or its causes or consequences. However, the Doctor at the PHC identified it as one of the major issues of concern in Kuthambakkam's public Health. The government also already started programs targeting high risk groups to tackle the issue through: Giving Iron tablets to school children on a weekly basis, fortifying the wheat given at *Aganwaris* to 0-3 children.

The PHC also gave iron tablets to all booked pregnant women by default. However, we realized there was a major problem with adherence and some people are missed if they are not in the Govt. Schools or the *Aganwaris*. One interesting observations for us was that a Doctor had to come in one of the schools every week to observe the over 300 students swallowing the pill. There were also talks about the unpleasant smell of pills or some side effects.

ANALYSIS/EXPERIMENTATION

We came up with a number of ideas for solving the defined problem (ideas like iron rich drinks, Moringa tea, iron fortified salt, lotions etc.) and we created flash cards and sketch models to test those ideas with community members. We also allowed community members to suggest their own solution.

During the tests, we realized that the community members wanted the process of getting iron to be as seamless as possible. They wanted a solution integrated in their everyday life. They also did not want to spend extra to get this solution. They wanted it at no cost or as an alternative to something they already pay for. Community leaders were also concerned about making the solution a means of empowering the community members economically.

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PRODUCT

Matching our observations from the community with our own goals, we decided to choose drinking water as the medium for providing iron supplementation.

This decision was further supported a number of studies that used drinking water as a vehicle for iron delivery. One of the studies was conducted in Brazil by Dutra-de-Oleveira et al where 31 pre-school children at a daycare center were given iron fortified water. Fortification was achieved by adding 20mg of iron per liter of water and giving the children every day for an eight month period. The blood levels were tested at the beginning and end of the study and anemia prevalence was observed to have dropped from 58% to 3%.[1,2,3]

This and similar studies simply showed water as a viable means for providing iron supplementation. Our goal was to then transfer the solution utilized in that research to the community.

There was a need to ensure first that the taste, color and safety of the water would not be affected and by using Sodium Iron EDTA at a concentration of 2mg per liter of water, it would be possible to contribute up to 40% of the required daily intake without affecting color or taste. Sodium Iron EDTA was also widely preferred as a safer iron salt for food fortification compared to Ferrous Sulphate.

We also needed to automate the addition of the Iron salt to the water since in the studies conducted, the iron salt was manually added to water in the required concentration every day. Our solutions to these were with two components of our product concept **(Figure 1)**

(a) An iron dispensing component which releases the required amount or iron for fortification.

(b) A siphon system which allows us to control the time a fixed volume of water is exposed to the dispenser.

> *The idea is to hold 10L of water for the same time it takes 20mg of Na Fe EDTA to flow into it from the dispenser and in this way the water that enters into the first chamber would have been fortified with iron. The iron fortified water then flows into a storage chamber that has a tap connected and from which household members take the needed water.*

We arrived at 10L fortification capacity by calculating the average daily water requirement (2L) by a family size of 5 members. We also estimate that the iron salt could be replaced once to twice yearly.

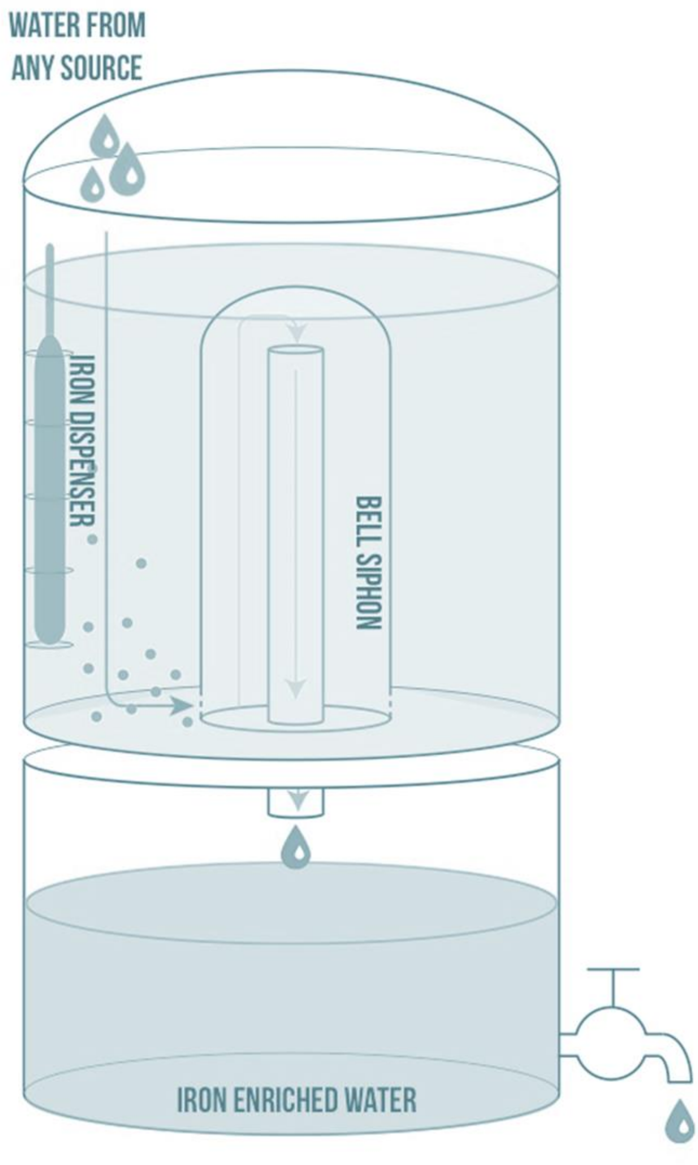


Figure 1: The H^{2}Pink *(Our design for iron fortification of drinking water in homes)*

THE IRON DISPENSING COMPONENT

The idea for the design of the iron dispensing component came from the generally known tendency of molecules to move across a concentration gradient through a membrane. We could better understand the dispenser from the way teabags work.

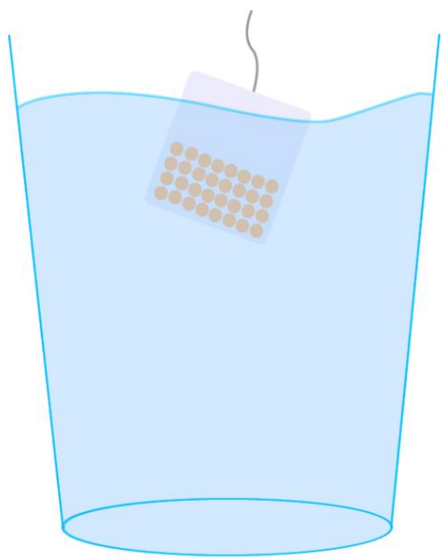


Figure 2: *A teabag in a glass of water*

When a teabag is dropped in water;

- Tea particles flow from within the teabag to the surrounding water
- Water molecules also flow from the surrounding water into the tea bag
- The nature of the teabag material also determines the rate at which these flows occur

However, for our design, we wanted flow of particles (Sodium Iron EDTA) from within the teabag to the outside but in a more controlled manner since we did not want all the iron particles to be released at once.

We also did not want water molecules to flow into the “teabag” since this might affect our iron salt i.e. Sodium Iron EDTA.

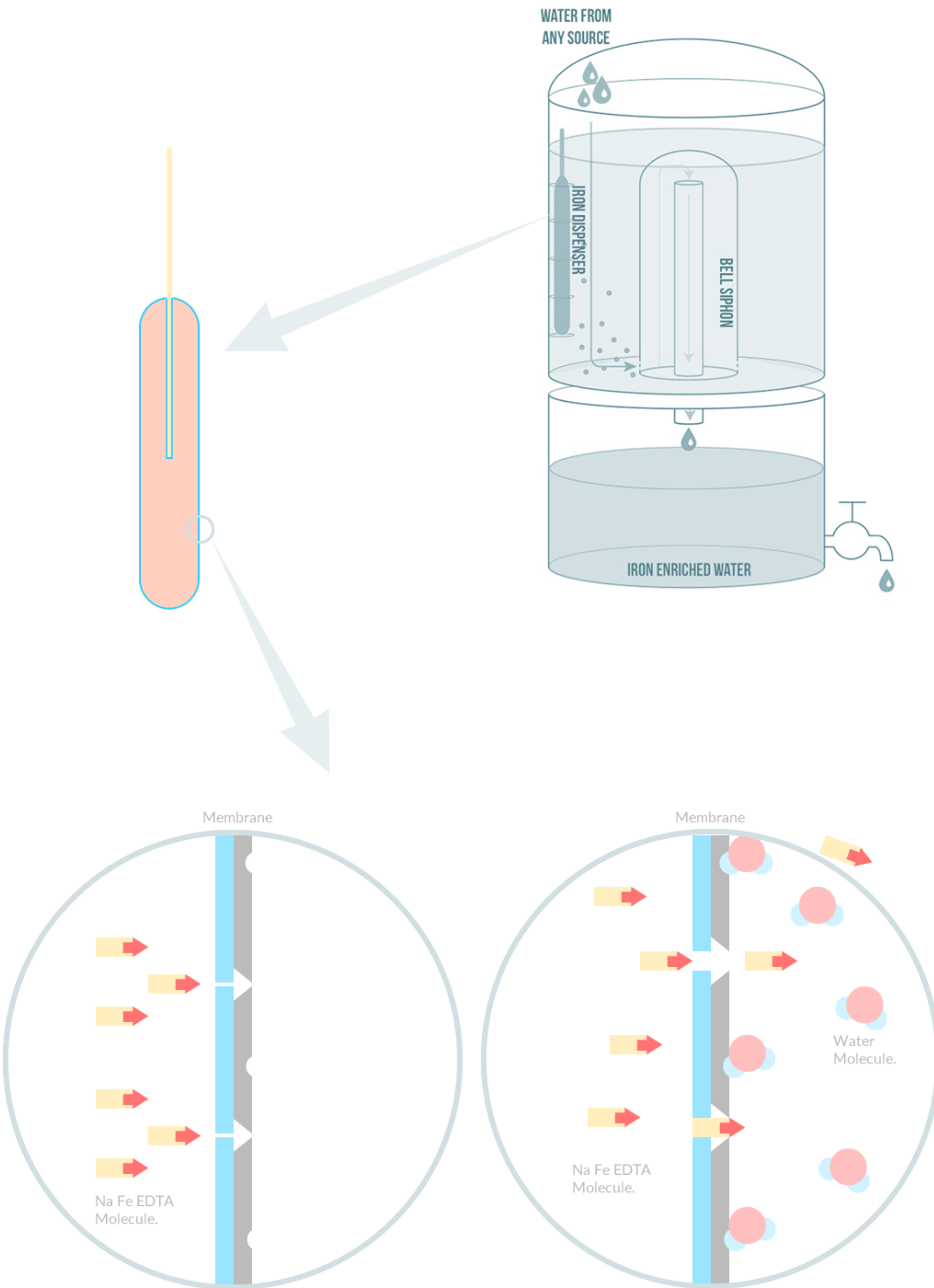
The goal was to then find a “teabag” material that would help us meet our needs. Our hypothetical material would have the following properties:

- Would allow flow of Sodium Iron EDTA from its inside to the outside
- Would not allow flow of water molecules from the surrounding water to its inside
- A flow rate that allows release time of 20mg of Sodium Iron EDTA to be between 2 to 4 minutes
- Ability to maintain these its material properties for up to a year

This hypothetical “teabag” membrane would be the wrapping material for the iron dispensing component of our device as shown in the diagram on the next page.

NOTES:

1. Dutra - de - Oliveira, J. E. ; Ferreira, J. B. ;Vasconcellos, V.P.; Marchini, J.S. Drinking water as an iron Carrier to control anemia in preschool children in a day-care center. Journal of the American College of Nutrition, v.13, n.2, pp.198-202, 1994.
2. Dutra - de - Oliveira, J.E.; Marchini, J.S.; Desai, I. Fortification of drinking water with iron: a new strategy for combating iron deficiency in Brazil. The American Journal of Clinical Nutrition, v.63, n.4, pp.612-614, 1996.
3. Dutra - de - Oliveira, JE, Almeida CAN. Domestic drinking water – an effective way to prevent anemia among low socioeconomic families in Brazil. Food and Nutr Bull v.23 (3 suppl), pp.213-216, 2002



No Water, Membrane inactive

Membrane pores remain closed and do not allow any flow of the molecules to the outside of the membrane.

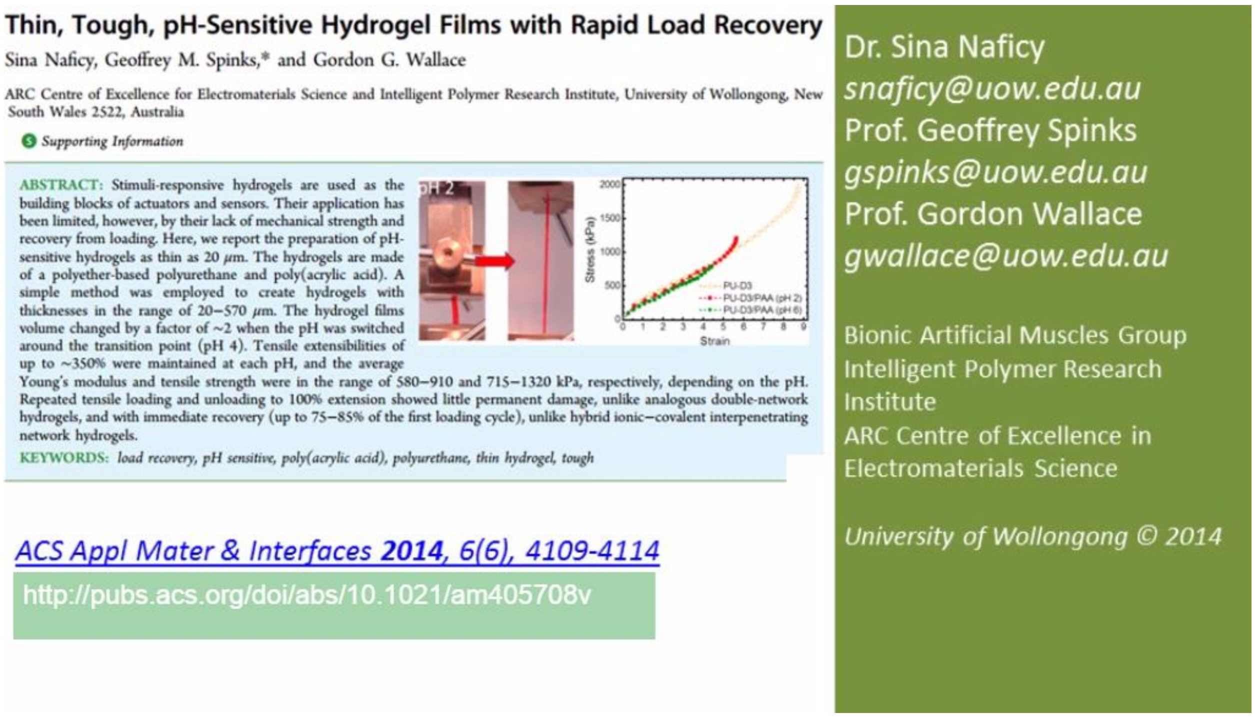
Water, Membrane activated

Na Fe EDTA Molecules flow in only one direction (from inside to the outside) Water molecules only activate the membrane and do not enter the inside.

MATERIAL BILL

1. Polymer Material:

   From our research, a pH responsive hydrogels is the best fit for this component. Below is a close sample we found on the internet.



Thin, Tough, pH-Sensitive Hydrogel Films with Rapid Load Recovery

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Supporting Information

ABSTRACT: Stimuli-responsive hydrogels are used as the building blocks of actuators and sensors. Their application has been limited, however, by their lack of mechanical strength and recovery from loading. Here, we report the preparation of pH-sensitive hydrogels as thin as 20 μm. The hydrogels are made of a polyether-based polyurethane and poly(acrylic acid). A simple method was employed to create hydrogels with thicknesses in the range of 20−570 μm. The hydrogel films volume changed by a factor of ~2 when the pH was switched around the transition point (pH 4). Tensile extensibilities of up to ~350% were maintained at each pH, and the average Young's modulus and tensile strength were in the range of 580−910 and 715−1320 kPa, respectively, depending on the pH. Repeated tensile loading and unloading to 100% extension showed little permanent damage, unlike analogous double-network hydrogels, and with immediate recovery (up to 75−85% of the first loading cycle), unlike hybrid ionic−covalent interpenetrating network hydrogels.

KEYWORDS: *load recovery, pH sensitive, poly(acrylic acid), polyurethane, thin hydrogel, tough*

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2. Casing (Acrylic or other materials used in building similar containers are a consideration)
3. Tap
4. Na Fe EDTA

Here, we repurposed a water dispenser tank to demonstrate the way the bell siphon works.

04

FUTURE

REFLECTION ON NEXT STEPS/ PROJECT VIABILITY

We understand that people might not necessarily be motivated by an appliance that helps fortify iron with water (we don't know, we can only assume until we test) so we are considering adding a water filter in the future so people do not have to buy just an iron fortification system for water but a device that also filters away impurities from water.

We also thought that creating a device that can be added into any water container that the user decides to make use of might be better off and more usable compared to having a system that requires the user to use just one container.

To be able to distribute the current product as it is, we have set a price goal of between $10 and $15; we think this would be low enough for the average family to consider buying one. However, we also hope to take advantage of the observed practice of distributing home appliances to citizens by the government. Other financial partners could also be helpful in getting the device to as many homes as possible.

The most important finding we observed is that amongst all the options we considered water seems like an interesting medium for increasing intake of iron by people. Had we gotten more time, we would have done further research into other possible options of using water for iron delivery beyond what we currently have.

INSPIRATIONS/LESSONS LEARNT

Here are some of the lessons learnt in the course of the project:

1. *It was interesting to work in a team with people from diverse fields and geographical regions. This also strengthened the project as individuals approached the problem in their own way and contributed from the knowledge they have from their own specialization. But there should be team spirit and commitment towards project continuity.*

2. *The "observe-ask-try" concept used to collect data works well and we learned that all the three should be implemented whenever possible. We could not try everything, but during our community visit at various stages we understood that observing people by shadowing them provides valuable information even though more volume of data can be obtained by asking them.*

3. *We have to be flexible and welcome any ideas given by others. It may seem like they are not working or not important to you but if you are not listening to them you may stop them from giving in additional inputs to you. During the problem framing and idea generation process, it was important to allow free flow of thoughts.*

4. *Brainstorming is an effective way of generating ideas. During the process, even ridiculous ideas should be recorded. This could bring in "out-of-the-box" thinking which leads to simple and effective ways of tackling the problem.*

5. *Co-design is an effective method that allows community engagement in design. It yields better results during the implementation of the project as the concerns of the local people (including their cultural/social behavior and financial limitations) are considered in the design of the product.*

Working on this project has also inspired team members to further explore some of the findings during the design process beyond the product itself.

> *Maya is interested in further exploration of the skin as a medium of drug delivery beyond iron supplementation.*

> *Ibrahim wants to study how skin patches (one of the technologies considered during the design process for iron delivery) could help access the bloodstream not just for drug delivery but for continuous monitoring of blood analytes*

Julias is currently doing a postgraduate project in material science and he considers pH responsive hydrogels (our "teabag" material for the iron dispenser) to be a viable research direction.

Richard would be pursuing a postgraduate degree in controlled drug delivery inspired his experience while working on the project.

IN 6 MONTHS/ TEAM ENGAGEMENT

Over the next 6 months, the plan is to take the project forward.

This would involve:

- Actual development of the iron dispenser component of the product, i.e. getting the necessary material which might involve help from technical experts in this area.
- Developing a high fidelity prototype and testing in Kuthambakkam to see how it fits well into the context of daily family life.
- We are also considering further research around water beyond our current product design.
- We also want to develop the best business model that would allow the solution to be distributed to as many households as possible (e.g. making it open source, other alternatives)

ROLES AND ENGAGEMENT

Julias who happens to be from Kuthambakkam and a professor at the BS Abdur-Rahman University has agreed to champion the project.

Other members of the team including **Maya, Ibrahim** and **Janet** (who was the Design Facilitator during the summit) have agreed to participate but their roles would be mainly supportive since they have other engagements. Other team members (**Nazalius**, **Puneet** and **Richard** are also very interested in the project but their current engagement makes it difficult to predict how they might be involved at this time)

The team would also be working very closely with the community partners in Kuthambakkam who showed a lot of interest in taking the project forward.

Communication would be majorly via digital media (emails, telephony, video/conference calls) and the team would initially meet at least once a week to continue work on the project.

A minimum of 2 hours of work/week would be contributed by the supporting team members at this initial stages and more by the project champion. Things may change in the future.

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