

Coagulation/Disinfection Technology for Treating Drinking Water  
in the Developing World

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**Abstract**

One of the technologies recognized by the WHO as effective in providing safe drinking water at the household level is a combination coagulation, flocculation, and disinfection treatment product developed through a collaborative effort between Procter & Gamble (P&G) and the US Centers for Disease Control and Prevention (CDC). Laboratory evaluations in test waters demonstrate that this product, called PUR Purifier of Water, effectively reduces waterborne pathogenic bacteria by more than 8 logs, viruses by more than 4 logs, and parasites by more than 3 logs. In addition, the technology reduces turbidity and removes a variety of chemical contaminants such as arsenic making it suitable for treating a wide variety of water sources in developing countries. Because the technology significantly reduces water turbidity, it provides superior microbial reduction compared to disinfection alone in highly turbid waters and provides a strong visual signal to consumers that the treatment is effectively cleaning the water. Four randomized, controlled, health intervention trials (n=25,000 people) demonstrated that the

combination system reduces the incidence of diarrhea by an average of 50%. In order to provide this new product, P&G has formed partnerships with a wide group of stakeholders including governments, academia, UN agencies, and not-for-profit organizations. Global emergency relief groups have used the product to provide safe drinking water during relief operations including for the Southeast Asia tsunami and the devastating earthquake in Pakistan. Independent monitoring of these relief efforts has demonstrated that the product is well-accepted by the local populations and results in reduction in diarrhea. These efforts have provided more than 300 million liters of safe drinking water in the developing world.

### ***Introduction***

Contaminated drinking water represents a major human health hazard in many parts of the world. The World Health Organization (WHO) estimates that 1.2 billion people are without access to safe and adequate sources of drinking water. A significant number of illnesses and deaths are reported annually as a result of waterborne diseases. Diarrhea-related illnesses alone are estimated to cause two million deaths per year and the majority of these deaths occur in young children.

The World Health Organization's document "Managing Water in the Home: Accelerated Health Gains from Improved Water Supply"<sup>1</sup> makes three statements that clearly support approaches of household water treatment.

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<sup>1</sup> WHO - Managing Water in the Home: Accelerated Health Gains from Improved Water Supply  
[http://www.who.int/water\\_sanitation\\_health/dwq/wsh0207/en/](http://www.who.int/water_sanitation_health/dwq/wsh0207/en/)

- 1) There is now conclusive evidence that simple, acceptable, low-cost interventions at the household and community level are capable of dramatically improving the microbial quality of household stored water and reducing the attendant risks of diarrheal disease and death.”
- 2) It is now well documented that the provision of safe water alone will reduce diarrheal and other enteric diseases by 6 to 50%, even in the absence of improved sanitation or other hygiene measures.
- 3) Overall, combined coagulation-flocculation and chlorine disinfection systems have shown considerable promise as microbiological purifiers of household water.

P&G has worked with the U.S. Centers for Disease Control and Prevention (CDC) since 1995 to develop reliable, cost-effective, clean water technologies. This collaboration has produced PUR Purifier of Water, a simple, affordable, in-home system for delivering clean water (a combination coagulation/flocculation/disinfection system). This product has potential for helping to address Millennium Development Goal 4<sup>2</sup> - Reduce child mortality - reduce by two thirds the mortality rate among children under five; and Millennium Development Goal 7 - Ensure environmental sustainability - reduce by half the proportion of people without sustainable access to safe drinking water.

P&G has devised a market-based strategy to bring safe drinking water to low-income populations in developing countries. Following several years of research to examine the acceptability and effectiveness of PUR, we are now pursuing large-scale marketing efforts in several countries using a social market-based approach with the assistance of

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<sup>2</sup> Millenium Development Goals - <http://www.un.org/millenniumgoals/>

Population Services International (PSI)<sup>3</sup>. Working with PSI gives P&G the ability to deliver PUR to low income consumers in remote or difficult reach to locations.

### ***The Product***

The PUR product was developed based on tests with thousands of consumers in developing countries. These consumers consistently said that they wanted visible signals that water was cleaner, at-home control of the process and affordability.

Purification of drinking water using PUR involves simple implements that consumers have in their homes. The contents of one small sachet are added to a 10 litre bucketful of water and mixed. The combined flocculation/ disinfection technology separates the dirt and other contaminants from the water within 5 minutes. The water is then filtered through a cloth to separate the floc. Clear water is ready to drink after a total of 30 minutes to allow for disinfection. Storage in a suitable container is recommended to prevent recontamination.

The PUR product reverse engineers the ‘gold standard’ of municipal, multiple barrier water treatment to create an affordable at-home water treatment system. A small sachet of powdered product provides precipitation, coagulation, and flocculation as well as residual chlorination. The product uses ingredients used in municipal treatment including ferric sulphate and calcium hypochlorite. The ‘end point’ of correct PUR use provides visible signals that water is cleaner. The product provides superiority to chlorine alone in

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<sup>3</sup> PSI is a nonprofit organization based in Washington, D.C. that harnesses the vitality of the private, commercial sector to address health problems, with programs in safe water, malaria, micronutrients, family planning and HIV/AIDS in more than 70 countries - [www.psi.org](http://www.psi.org)

performance in turbid waters and reduction of organics / heavy metals. The product has stability without special handling for three years from the date of manufacture and provides the potential for long-term consumer use as well as use for providing emergency water.

### ***Results***

Laboratory tests have demonstrated that PUR reduces the levels of 14 types of representative waterborne bacterial pathogens including *Samonella typhi* and *Vibrio cholerae* from concentrations of  $10^8$ /litre to undetectable (less than 1/litre). See Table 1 below.

**Table 1. Bacteria removal**

<u>Bacteria</u>	<u>Initial</u> (org/liter)	Post- <u>Treatment</u>
<i>E. coli</i>	$2.0 \times 10^8$	ND
10 common fecal bacteria	$9.2 \times 10^9$	ND
<i>Salmonella typhi</i>	$1.6 \times 10^8$	ND
<i>Vibrio Cholerae</i>	$1.2 \times 10^8$	ND
<i>Shigella sonnei</i>	$2.2 \times 10^8$	ND
<i>Klebsiella terrigena</i>	$2.8 \times 10^8$	ND
<i>Campylobacter jejuni</i>	$2.0 \times 10^8$	ND

ND = None Detected

No *Escherichia coli* were detected after treatment in 320 field test water samples collected from five developing countries. In addition, PUR reduced viral concentrations of polio and rotavirus by greater than 5-log values. See Table 2 below.

**Table 2. Virus removal**

<u>Virus</u>	<u>Initial Viral Count/ml</u> (log 10)	<u>Mean Log Reduction</u>
Poliovirus	7.1	>5.0
Rotavirus	7.9	>5.0

The concentration of pathogenic protozoa such as *Cryptosporidium parvum* and *Giardia lamblia* were also reduced by greater than 3-log values following use of PUR. See Table 3 below.

**Table 3. Cyst removal**

<u>Cyst</u>	<u>Mean Initial</u> (org/liter)	<u>Mean Log Reduction</u>
<i>Cryptosporidium parvum</i>	$1.76 \times 10^6$	4.0
<i>Giardia lamblia</i>	$1.84 \times 10^6$	3.6

PUR also significantly reduces concentrations of heavy metals from contaminated drinking water. See Table 4 below.

**Table 4. Heavy Metals reduction**

<u>Heavy Metal</u>	<u>Initial</u> (ppb)	<u>Post-Treatment</u> (ppb)
Arsenic	543	0.8*
Arsenic (Bangladesh)	229	1.2*
Chromium (III)	1300	3.1*
Lead	270	<10*

\*Below WHO Guidelines

A study in Bangladesh conducted by the CDC showed that when used by consumers on a daily basis for 3 months, PUR significantly reduced arsenic in contaminated tubewells with 88% of the samples having arsenic below the Bangladesh guideline of 50 µg/litre. Studies also show that PUR can remove organic compounds and certain pesticides from contaminated drinking water, see Table 5 below.

**Table 5. Organics and selected pesticide removal**

<u>Test Material</u>	<u>Initial</u>	<u>Post-Treatment</u>
Humic acid (ppm)	24-30	<1
DDT (ppb)	6	0.34

WHO Guideline for DDT = 2 ppb

Field testing also showed that PUR effectively reduced the turbidity of a wide range of different water samples, see Table 6 below.

**Table 6. Effective\* turbidity removal in a wide variety of field samples**

<u>Country</u>	<u>Initial NTU</u>	<u>Treated NTU</u>
Guatemala	0 – 501	0.0 - 2.6
Kenya	0.7 – 1850	0.4 - 3.2
Morocco	0 – 244	0.0 - 1.1
Philippines	0 – 550	0.0 - 1.2
Bangladesh	10 – 35	0.0 - 1.1
South Africa	<0.2 – 54	0.2 - 0.4

\*Effective microbiologically as well as improving clarity

Five randomized controlled health intervention trials (four conducted by the CDC and one conducted by Johns Hopkins University) demonstrated that PUR can reduce diarrheal illness. The average reduction in these trials was 50%. Table 7 shows the range of reduction and the number of participants in these trials.

**Table 7. Results of randomized, controlled health intervention studies with PUR**

<u>Location/Setting</u>	<u>Study Design</u>	<u>Diarrhea Reduction</u>
Rural Guatemala	2982 people, 52 weeks	24-29% reduction
Rural Guatemala	3401 people, 13 weeks	40-72% reduction
Rural Kenya – turbid water	6615 people, 20 weeks	17-42% reduction
Pakistan – urban setting	12090 people, 39 weeks	59-64% reduction
Liberia – refugee camp	2191 people, 12 weeks	87-95% reduction

\*Reduction in diarrhea prevalence vs controls who retained traditional practices



PUR has been used in the Philippines, Guatemala, Morocco, Pakistan, Haiti, Liberia, Bangladesh, Kenya, Uganda, Chad, Botswana, Malawi, Zimbabwe, Sudan, Iran, Ethiopia, Iraq and the tsunami ravaged region of South East Asia. Since 2003, PUR has been used to provide more than 300 million liters of safe drinking water.

### ***Innovation***

The PUR project has developed an innovative approach to the provision of clean and safe drinking water to people in developing countries. Conventional methods of building additional infrastructure to supply clean, treated drinking water need complementary approaches in order to meet the Millennium Development Goals (MDGs). For example, it's estimated that an additional US \$180 billion in international aid would be necessary to meet the MDGs via supplying piped-treated water, and 150,000 additional people would need to be connected everyday between now and 2015.

The conventional methods of supplying drinking water, piped-treated or well water typically do not provide reliably safe supply at the household level in the developing world. The PUR point-of-use model, combined with safe storage, has the advantages of acceptable cost, immediate availability, ease of distribution to reach rural areas, and long-term product stability (e.g. shelf life). In both the short and long term this point of use approach is complementary to the development of piped water infrastructure.

### ***Marketing Innovation***

P&G have chosen to support manufacture and distribution of the PUR sachets as their focal corporate philanthropy program, called the Children's Safe Drinking Water. This

is part of a broader philanthropic focus within P&G of helping children in need – called Live, Learn, and Thrive. As part of the program, P&G provides PUR at a cost of \$0.035 per sachet plus shipping for use in sustained social markets as well as emergency relief. P&G has also invested more than \$5 million in this philanthropic effort during the last three years.

‘Social’ Marketing - P&G have provided the technical R&D skills to deliver an effective and affordable product. This is only the first hurdle in order to provide a low cost method of purifying water in the home for those in developing countries who do not have access to improved water infrastructure, or where the water from such an infrastructure is not safe. In order to achieve this objective, P&G has set up a number of partnerships with NGO’s, local and national governments and health organisations. The innovative aspect of the project management lies in development of the consumer marketplace as an, as yet, untapped source of new financing for safe water, and its distribution, particularly in areas not yet served by an improved water infrastructure.

To achieve this P&G have looked at an alternative set of marketing and product delivery options. This is because the ‘regular’ P&G marketing model, refined from many years of providing products to consumers in the developed world, just does not meet the requirements of those people in the developing world. The regular marketing model relies heavily on a pre-existing infrastructure of transportation, retail outlets and ‘traditional media’ - to get out educational messages etc....This structure frequently does not exist in many developing countries and as such a new approach was needed.

Social marketing combines education to motivate healthy behaviour with the provision of needed health products and services to lower-income persons. PSI is helping to establish

distribution systems and sell PUR through the local wholesale and retail network; primarily to lower-income persons.

By combining this approach with the provision of ‘micro-credit’ loans this enables local people to obtain the seed funding to set up their own businesses (village shops, rural distribution companies etc....), purchase PUR at ‘cost’ (neither P&G or PSI make any profit out of this transaction) and sell it at retail price. The profit from this will enable them to develop their businesses, pay back their initial loan and purchase further shipments of PUR.

P&G and PSI are working closely with a variety of other organisations; teachers, nurses (through the International Council of Nurses - ICN<sup>4</sup>) doctors, church leaders, humanitarian organisations, such as CARE<sup>5</sup> to educate the local population about the need for safe water and demonstrating PUR in use.

The USAID<sup>6</sup> and DFID<sup>7</sup> have both provided funding to help set up PUR social market in Haiti, and P&G launched social markets in Uganda, Kenya, the Dominican Republic, and Malawi.

Emergency relief – This has been developed to help address the millions of people who every year lack access to safe drinking water because of natural disasters or because of armed conflicts. PUR has several potential advantages for emergencies including long-

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4 International Council of Nurses - [www.icn.ch](http://www.icn.ch)

5 CARE - [www.care.org/](http://www.care.org/)

6 US Agency for International Development have provided \$1.4 million for PuR® work in Haiti - [www.usaid.gov](http://www.usaid.gov)

7 The UK governments Department for International Development have provided £224,000 for PuR® work in Haiti. - [www.dfid.gov.uk](http://www.dfid.gov.uk)

term stability so it can be stockpiled in areas of frequent disasters, ease of transport as light-weight and non-hazardous material, and robustness to treat even very turbid surface waters. Simple education materials in multiple languages have been developed for the combination system to allow for rapid deployment. The packaging of the product in small sachets is stable and convenient to store over long periods of time making it ideal for inefficient distribution chains in the poorest of countries, and for emergency and disaster relief use.

With the devastating occurrence of the tsunami in South East Asia at the end of 2004 PUR has demonstrated that it is a valuable tool in quickly and effectively providing a supply of safe, clean water 'in the field'. Working with a variety of partners, P&G shipped 15 million sachets of PUR into the region (enough to provide 150 million litres of safe clean water). In addition, PUR has been used in more than a dozen countries by more than a dozen emergency relief organizations. A massive intervention is currently underway in Pakistan to help victims of the earthquake in the region.

### ***Sustainability***

Considering the PUR product in the context of sustainability or sustainable development, requires us to address the environmental, economic and social issues surrounding the product. From an environmental perspective the product cleans water using ingredients used in conventional water treatment technology and the small volume of waste is a ferric sludge that can simply be disposed of in a latrine. From an economic perspective it is

planned that the product be produced in a developing country, bringing economic development to the region and sold at an affordable price of US \$0.01/litre or less of treated water. The social aspects of this product include benefits such as saving lives, reducing the burden of disease and helping people out of poverty by reducing medical bills and improving availability for work.

### ***Furthering Global Partnerships***

The provision of safe clean water is a major challenge, one that requires the active engagement of a number of different organisations. As such we realise that P&G is just one of a number of players that need to work together to achieve a common objective – the provision of a low cost method of purifying water in the home for those in developing countries who do not have access to improved water infrastructure, or where the water from such an infrastructure is not safe.

P&G can provide the technical R&D skills to deliver an effective, affordable product and the ability to manufacture the product in the volume required – but we need partners to provide other unique skills:

- rural transport networks
- rural sales outlets
- independent / trusted educational programs
- disaster relief knowledge

In order to bring together a group of like minded organisations we have helped to set up The Safe Drinking Water Alliance<sup>14</sup> . The Alliance is a strategic public-private collaboration to develop innovative program approaches for ensuring the safety of household water intended for human consumption. In late 2003, the U.S. Agency for International Development (USAID), Johns Hopkins Bloomberg School of Public Health/Center for Communication Programs<sup>15</sup>, CARE, Population Services International, and P&G joined forces to leverage their respective expertise and resources to better understand the behaviours and motivations for choosing particular technologies for treating household water, share the knowledge gained, and identify opportunities for scaling up successful efforts to ensure safe drinking water.

P&G is also a member of the WHO's International Network to Promote Household Water Treatment and Safe Storage<sup>16</sup>. The aim of the Network is to contribute to a significant reduction in waterborne disease, especially among vulnerable populations, by promoting household water treatment and safe storage as a key component of water, sanitation and hygiene programmes.

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14 The Safe Drinking Water Alliance - <http://www.pghsi.com/images/SafeDrinkingWaterAlliance.pdf>

15 Johns Hopkins Bloomberg School of Public Health/Center for Communication Programs [www.jhuccp.org](http://www.jhuccp.org)

16 The International Network to Promote Household Water Treatment and Safe Storage  
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