Avoiding fluoride in drinking water, Andhra Pradesh, India

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Increased exploitation of groundwater for irrigation is one factor leading to dangerously high levels of fluoride in drinking water in parts of India. Involving local people in testing and monitoring can help to find safe sources. It is then important to protect sources by improving local recharge and reducing nearby extraction.

The Reddy family who live in Battuvani Palli, a rural village in southern India, have suffered for more than five years from the effects of drinking water that contains high amounts of fluoride. Their daughter has chronic skeletal fluorosis, meaning that she will never be able to walk properly and is destined to be a social outcast. Their son has severely discoloured teeth: a tell-tale sign that water contains dangerous levels of fluoride. All the other family members suffer from aching joints, which make any kind of manual work very difficult, and even sleeping is disturbed by pain. This is a typical story from one of the increasing number of villages that are affected by fluoride in drinking water.

The NGO Acción Fraterna is helping to solve such drinking-water problems in this part of Andhra Pradesh. The methodology they developed was to incorporate integrated, participatory and problem-focused approaches to improving water management into the pilot implementation of a watershed development programme. This paper explains how watershed programmes can, and arguably must, address water-quality issues that are linked, in may cases, to over-extraction of groundwater.

Over-exploitation of resources

Extensive exploitation of groundwater, made possible by enormous public and private investment in borewells for farmers, has had huge benefits for agricultural production and rural livelihoods in rural India, especially over the last decade. But an important negative side effect has been the reduced local availability of water for village domestic supplies, leading to insufficient water to sustain communities through drought periods.

Less well known are the impacts of unsustainable levels of groundwater development on the quality of drinking water available in villages. In areas where groundwater levels have fallen and rocks contain fluoride-bearing minerals, longer flow pathways of underground water can lead to higher fluoride levels. Similar effects seem to cause fluoride levels to rise during droughts. Furthermore, uncontrolled borewell development means that in areas with water-quality problems, such as where there are naturally high fluoride levels, the few available underground 'pockets' of good quality water are frequently used for irrigating crops.

Fluoride in drinking water

Fluoride occurs naturally in some groundwater sources (linked to the presence of minerals like fluorspar, cryolite and fluorapatite) and in foods that have been grown or produced using water with high fluoride content. Ingestion of large amounts of fluoride can cause serious health problems for humans and animals (see Table 1). These range from discoloured teeth (i.e. dental fluorosis) to aching joints, brittle bones, stunted growth and deformed limbs (i.e. skeletal fluorosis).

Table 1 Effects of fluoride in drinking water

Fluoride concentration (mg/l)	Effects
Below 1.0	Safe
1.0–1.5	Marginal
1.5–3.0	High risk of dental fluorosis
3.0–10.0	Leads to skeletal fluorosis with adverse changes in bones
More than 10.0	Crippling skeletal fluorosis

The current World Health Organisation permissible limit for the fluoride concentration of drinking water supplies is 1.5 mg/l (or ppm) with the added recommendation that 'climatic conditions, volume of water consumed and intake from other sources should be considered when setting national standards'. In 1993, the Bureau of Indian Standards set a maximum permissible fluoride concentration of 1.0 mg/l, although concentrations of up to 1.5 mg/l are considered to be acceptable in the absence of an alternative safer source.

Because fluoride levels in groundwater are hugely variable, even across short distances, and because of the impacts of development, there is a need for 'catchment' scale solutions to mitigate fluoride problems in aquifers used for domestic supply. Such solutions should make sure that: the best quality water available is used for drinking and that the causes of groundwater over-exploitation are addressed. Unsustainable groundwater use can only be tackled by a combination of improved recharge in areas near to domestic sources (e.g. by judicious location

Symptoms of skeletal fluorosis

of water-harvesting structures) and reduced groundwater extraction near to these critical sources (e.g. by zoning).

Case study

One example of how local solutions can sometimes work is the village of Battuvani Palli in Andhra Pradesh. Here, Acción Fraterna undertook participatory fluoride surveys (Box 1) as part of a watershed development programme. Watershed development programmes in the area typically had previously focused on activities like promoting tree-crops to enable farmers to diversify from groundnut monoculture, and constructing check-dams and other water-harvesting structures to catch more water for irrigation. Generally such programmes ignore domestic water-supply issues, even though domestic water-supply problems are often related to patterns of 'watershed management': especially groundwater development. However, Acción Fraterna were motivated to investigate more integrated options to development, and had noticed the prevalence of health problems that might be linked to fluoride in drinking water.

The results of fluoride surveys in Battuvani Palli using portable field kits were of huge interest to villagers, many of whom suffered from symptoms of fluorosis. The day after the surveys were completed, people were busily exchanging results and had memorized most of them. They wanted information to understand why they were suffering health problems and, more importantly, to start discussing solutions. The villagers' interest in and acceptance of results contrasted starkly with the reaction from district-level authorities who stuck firmly to the official line that there was not a fluoride problem in the village. It was only after approximately 12 months of interactions that these

Box 1. A methodology for participatory fluoride surveys

Measurement techniques

Methodologies available to monitor fluoride in water samples include:

- *Laboratory analysis*: reliable, but usually slow, which leads to long delays in giving feedback on results to communitie.
- *Portable field kits*: these can be reliable if the kits (based upon colorimeters or ion-selective electrodes) are used properly, and make it possible to feedback results. quickly, as well as sampling a large number of sources across areas quickly. In this study, a HACH portable colorimeter was used (HACH pocket colorimeter Type I, Hach Company, Loveland, Colorado).
- *Indicator test strips*: these can make analysis very participatory and are useful for raising awareness on fluoride problems, but are not sufficiently reliable for potential life-and-death decision-making.

Sampling

In the vicinity of the study villages, water samples were collected from each well within approximately 2 km of the village centre. This included the main domestic water-supply sources for the villages, but also other sources like irrigation wells in order to provide information on the (large) variations in fluoride levels around the villages where better quality water might be available. Information on the type and use made of each well was also collected, and using a GPS system, the exact location was also logged. Occasional measurements were also made of surface water in tanks and check dams that are used to recharge groundwater. Given the high levels of temporal variation, important sources were monitored regularly (monthly).

Training and testing

Samples were analysed using the manufacturer's prescribed 'pipette' method. This requires use of standard fluoride solutions to calibrate the meter, and adding reagents to water samples, so users must be experienced and careful. Training should be given to check that the procedure recommended by the manufacturer is carried out, and to check results for consistency (by repeating tests) and reliability (by comparison with results from laboratories). Our testing period showed that we would also need to dilute samples with distilled water by a ratio of 2:1 in order to remain within the measurement limits of the equipment.

Analysis procedures

Samples were analysed using the colorimeter in a temporary laboratory – a clean room with space to layout the samples and equipment – usually on the same day as sample collection, either within the village or nearby. After solving problems revealed by the initial cross-checks (poor results due to procedure, dilution etc) it was possible to complete 10–15 tests in an hour.

Calibrations of the portable meter were regularly checked against standard fluoride solutions, and samples sent to other laboratories for cross-comparison. Regular checking of different batches of samples over time, tests by different operators, and with different laboratories are important to reveal possible errors. It is useful to plot the field and laboratory results together in a scatter graph and to look for differences and patterns. In order to triangulate the findings of the surveys, results were compared with results from a rapid assessment where water users had been asked to assess the quality of water from domestic sources on the basis of taste and whether they felt the water contained fluoride.

Feedback of results

Participation of the community in collecting water samples was encouraged, so that people understood the objectives of the survey and felt some level of ownership of the findings. Equally important, results were then rapidly reported back to the community and well owners. Wells where fluoride levels exceeded the safe limit of 1.5 mg/l were marked with a red cross to indicate that the water was considered unsafe for drinking.

Undertaking fluoride measurements locally

authorities started to accept the findings of the preliminary surveys and to recognize that people in these villages have been suffering because of the water quality of their drinking-water supply. Health problems are not routinely linked to the monitoring of the performance of water-supply systems.

As part of a participatory planning process, ideas for solutions were developed that included:

- Treatment: Given the existing plentiful water supply, despite very high fluoride levels, household- or community-level treatment of water was an option. Filters and lower-cost treatment methods were both tried, but neither was considered to be an adequate solution due to high cost or limited effectiveness.
- An alternative source for drinking: eight out of a total of 65 irrigation wells sampled in the vicinity of Battuvani Palli recorded fluoride levels below the safe limit of 1.5 mg/l (in the range 1.04–1.46 mg/l). There was a cluster of wells about 2 km south of the village (see Map) where a new source could be sited, however this area was disputed with a neighbouring village. A borewell that was drilled in the tank bed and close to some low fluoride sources turned out to be unsafe.
- Recharge of the existing source and management: It was thought that enhanced recharge in the zone close to the existing well and management of water levels in the area (e.g. by restricting pumping from adjacent irrigation sources) might influence fluoride levels.

Eventually, an irrigation well with safe fluoride levels (1.5 mg/l in early 2004 compared to the 3.8 mg/l of the existing source at this time) was used to develop a new drinking-water supply for the village (see map). This provides a limited quantity of relatively low-fluoride water to supplement the existing domestic supply. The farmer who provided this well was compensated, and a new short pipeline was laid to take safe water to the village. Rapid health improvements were reported. However, the quality of this water will need to be monitored regularly and the source protected.

By March 2005, after a prolonged dry period, fluoride levels had risen to an unsafe, although still improved, 1.7 mg/l. While new borewells within 300 metres have been prevented, 30 new borewells were drilled in the village in the previous year and recharge has been low. The community are now considering construction of a check dam to enhance recharge of the source, and the village water committee has already had to reduce daily water collection from the low-fluoride source to 50 litres per household and only 25 litres during summer.

Conclusions and recommendations

Participatory fluoride surveys linked to improved watershed management could bring relief to some of the hundreds of thousands of people who are currently suffering from fluoride poisoning throughout India. The need for much better monitoring and mitigation measures, both areas where rural communities are clearly able to play a vital role, should build upon the routine use of participatory surveys by government line departments and a broader

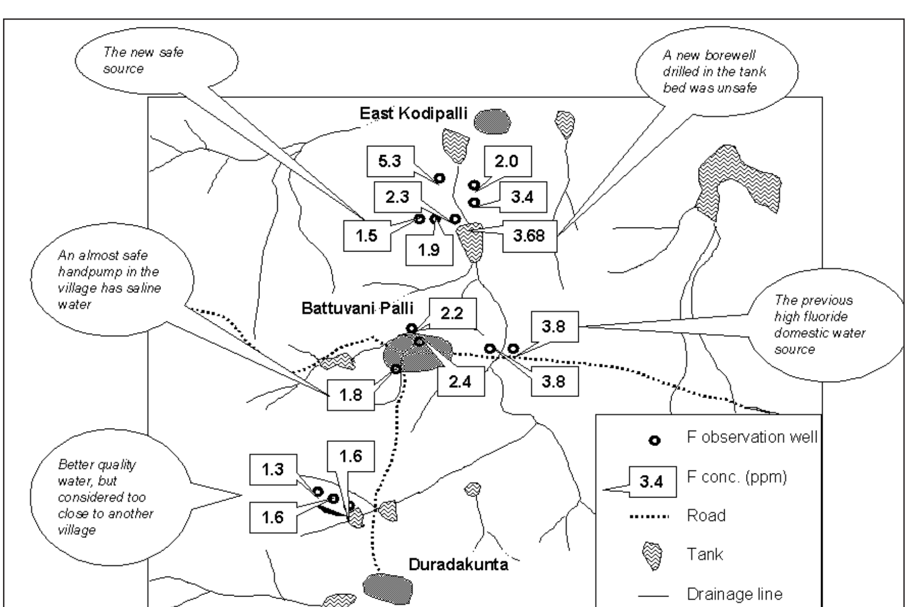

Figure 1 The location of some key monitoring wells in Battuvani Palli