Supplementary Information: Working Group Reports

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1. Industrial Pollution: related issues and its control

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1.1. Background

The State of West Bengal has a GDP of ₹10.49 lakh crore (US$150 billion), of which 25% is from Industry[1]. The majority of GDP (56%) is from Services, with the remaining 19% from Agriculture. There are up to 10,000 registered factories in the state mostly concentrated in the Kolkata region, the mineral-rich western highlands and Haldia port region. Industries include the processing of jute and other agricultural products such as tea and sugar, steel manufacture, and the manufacture of chemicals, fertilisers and pharmaceuticals, and the leather industry. Although the majority of the heavy industries are located in the north of the state, particularly in the Durgapur region, there are a number of large factories in Kolkata and approximately 25 percent of India's tanning activity is undertaken in Kolkata and its suburbs. The most important manufactured goods in the Kolkata district are engineering goods, leather products, rubber products, jute products and personal care products. In addition there is a large dock area. Nevertheless, service industries, particularly IT, are the major employer in the region.

1.2. Key Observations from Field Excursions

From the field trips and discussions with stakeholders it was clear that the large scale industrial units in the Kolkata region are well aware of water quality issues and the need for waste water treatment, and are regulated. According to the provisions of Water (Prevention and Control of Pollution) Act, 1974 and Air (Prevention and Control of Pollution) Act, 1981 all new industrial projects are required to obtain "Consent to Establish" (popularly termed as NOC - No Objection Certificate) from the State Pollution Control Board. Depending upon the pollution and hazardous potential of industrial activities, there may be siting restrictions for these industries. All industries require a "Consent to Operate" from the State Pollution Control Board, which is time limited, with the more polluting industries (classed as Orange or Red) requiring renewal more frequently than industries classed as Green. Red (maximal pollution potential) industries are not permitted in the Kolkata Metropolitan Area, and Orange (moderate pollution potential) industries are restricted to designated industrial areas of the Kolkata Municipal Corporation and Howrah Municipal Corporation areas.

The large factories, including those visited manage their waste carefully as they are under the inspection of the WBPCB and are risk averse, taking care to avoid being shut down if they violate the terms of their consents. The companies we visited had their own waste water treatment facilities and took pride in ensuring compliance with their discharge consents.

On the other hand, many drains carry domestic and industrial wastes from small industries and from dumping of solid waste on the river banks, all of which contributes significantly to river water pollution[2]. This was confirmed from our observations on the excursions, where we observed widespread small and/or backyard industrial units, and many places where waste was dumped on river banks, apparently illegally. Although the flesh from the fish from the East Kolkata wetlands achieves metal (Cd, Cr, Pb) safety standards for human consumption, the livers, gills and guts often fail, suggesting that the waste water entering the East Kolkata wetlands is high in metals: it is likely that the waste water in the canal is a mixture of effluent from both domestic and small scale industrial sources. Managing pollution from such diffuse industrial sources presents numerous challenges, particularly where effluent is mixed with domestic sewage. The

Front cover image: Kolkata, India (Photo credit Emma Bennett, IUKWC) treatment of combined industrial/domestic sewage is a problem globally, as they require different processes to remove potential pollutants, and industrial pollution can reduce the efficiency of treatment processes designed to treat domestic sewage.

The WBPCB monitors water quality in 105 surface water bodies in the state, including rivers lakes and ground waters that have the potential to be impacted by industrial activity. The rivers are assessed on a monthly basis for physico-chemical and bacteriological parameters like pH, TSS, DO, BOD, COD, ammonia, nitrate, total Kjeldahl nitrogen, total coliform bacteria, faecal coliform bacteria, etc. Heavy metal and pesticide concentrations are monitored once a year, in April, following the protocols of the Central Pollution Control Board.

Water quality in the Hooghly River is assessed every month at 10 monitoring stations (Berhampore, Nabadip, Tribeni, Palta, Serampore, Dakshineswar, Garden Reach, Howrah Shibpur, Uluberia, Diamond Harbour)[2]. The monitoring stations have been selected to provide a good coverage

Fig 1. Raw water abstraction point, Bagbazar.

and to protect abstraction points for drinking water. The distribution of monitoring stations provides an effective network for regulation. Although DO is generally high, BOD fluctuates and bacteriological parameters indicate widespread contamination with domestic sewage.

1.3. Assessment of the problem

As the concentrations of faecal coliforms in river water are frequently high, the WBPCB consider domestic sewage more of an issue in the Kolkata region and the Hooghly River than industrial pollution. Waste from large scale industrial units is managed well and often treated on site: the WBPCB do not consider industrial pollution from these large scale sources to be a problem. Nevertheless, it is acknowledged that many drains carry industrial wastes from small industries and from dumping of solid waste on the river banks, along with domestic sewage[2]. It is likely that domestic sewage is contaminated with waste from small scale industrial activities.

As well as well-known industrial pollutants which the WBPCB monitor for (e.g. metals, pesticides), there is the potential for other contaminants from small scale industry (such as plastic recycling, textile industries) and domestic sources entering drains. These variously include organic compounds, halogenated hydrocarbons, pharmaceuticals, waste products from the textile industries, agrochemicals, microplastics and other emerging contaminants. Regulators worldwide are becoming increasingly concerned of the potential risk that such emerging contaminants may present.

The group expressed concerns that issues may arise through the entry of these emerging pollutants into the food chain and bioaccumulation, and thus a risk to human health. This will be enhanced by aquaculture/agriculture practices based on use of sewage as a fertilizer. There is also the possible contamination of aquifers. These concerns are not restricted to India: emerging pollutants are a global concern.

Additional concerns are based on the potential combination of pollution from small scale industries with organic sewage, which is likely to lead to biotransformation and change in speciation of contaminants, and thus potentially increase the risk. Furthermore, for many contaminants there is the potential that they may become combined with sediments leading to legacy effects even

Fig 2. Dumping of waste on riverbanks.

Fig 3. A mixed landscape of small-scale industry and domestic areas

Fig 4. Canal water used to supply the East Kolkata wetlands and fisheries

though they may not be evident in the water column. In addition, the group members critically discussed on non-point sources which has being polluted the river and expressed to design a management framework to control such unidentified pollution at source itself.

1.4. Research to address Industrial Pollution, Related Issues and its Control.

At the current time there are insufficient data to determine if small scale and/or backyard industrial activities are causing a substantial problem. The data collected by the WBPCB have been optimized to provide effective regulation of water quality. It may be possible to determine if industrial activities are causing a substantial problem using these existing data, following a before-after-control-impact (BACI) design, but these monitoring data, whilst ideal for regulation, are not designed for this purpose. The group suggested that a network of monitoring stations, potentially using sensor technologies, specifically designed to assess potential sources of pollutants from dispersed small-scale/back-yard industries may help to determine the scale of the problem.

There is the need for analytical tools that are cost-effective. For emerging contaminants this may be particularly challenging, but some technologies (e.g. passive samplers, HPLC-MS screening) can provide time-integrated measures of a wide range of determinands at moderate cost. Biomonitors can also be used, where the extent of accumulation of toxic substances by the local fauna is used as a measure of the extent of contamination.

Low-cost alternatives include the use of biological monitoring using the reference condition approach. This approach forms an important strand of the detection of pollution in Europe and North America. By comparing the biota found at a site with that expected if the site were not suffering from pollution, it is possible to assess the extent of pollution, and thus reduce the number of sites that require samples to be processed using more expensive analytical techniques.

Another cost-effective approach that could be applied would be the use of GIS based models for mapping potential sources/hydrological pathways and, thus, identify locations that present the greatest risk, and thus target on the ground monitoring. Existing data (e.g. from Consent to operate) could be used to determine density of likely sources of contaminants from small-scale industrial units, and road networks/satellite imagery for risk from illegal dumping. Conceptual models would have to be developed based on risk of discharge and overland flow. Scenario modelling using climate models/rainfall data could be used to assess future changes in risk.

The overall objective would be to identify where the combination of industrial and domestic pollution may reduce the effectiveness of any treatment of waste water.

References

[1]Centre for Budget and Governance Accountability, India (2018) West Bengal Budget Analysis 2018-19

[2]West Bengal Pollution Control Board Annual Report, 2016-2017

http://www.wbpcb.gov.in/writereaddata/upload/contents/File-29.pdf

2. Natural pollution by arsenic and fluoride

Dr Surajit Chakraborty, Dr Rajib Chattopadhyay, Prof John M. McArthur and Prof Pradip K. Sikdar

Note: The remit included fluoride, but no fluoride problems were seen, nor were they discussed, so we focus on arsenic.

2.1. Nature and Magnitude of the Problem

The problems are that human consumption of groundwater containing > 10 μg/L of arsenic of > 0.75 mg/l of fluoride (in hot climates) is problematic for human health and the adverse effects increase in severity the higher the concentrations in the water consumed. Consumption of groundwater is made necessary in monsoonal India by the lack of rain in the dry season. Another issue is that arsenic-rich groundwater used for irrigation enriches soils in arsenic and leads to crop failure, e.g. rice develops straight-head disease and gives no grain when subject to arsenic stress.

The magnitude of the problem for human health posed by arsenic and fluoride is known anecdotally to be great, with estimates of 150 million people exposed to health risks from arsenic and 200 million exposed to health risks from fluoride. The basis for these figures is obscure and involves much extrapolation. Validating evidence to scope the severity and extent of each problem are in short supply, but even if the figures are wrong by a factor of 5, the problems are still severe. There appears to be no estimates of the severity or magnitude of the threat to crops posed by arsenic pollution in groundwater, nor much perception at government level that such a problem exists.

2.2. How well do we understand and assess the potential impacts?

The personal impacts of arsenic pollution of groundwater on human health are well known from epidemiological studies in Bangladesh and Chile that are rigorous but limited in geographical scope. How cause/effect relations translate into impact on human health across West Bengal is not clear. For arsenic, numerous large-scale survey appear to have been completed across West Bengal, including by the Department of Science and Technology and Prof. Dipankar Chakraborty of Jadavpur University. These surveys cannot be used to estimate health impacts because the data from them are not in the public domain. Their summary results are therefore suspect. For example, a map of arsenic-affected areas in West Bengal is available on the website of the Public

Health Engineering Department (PHED) (http://maps.wbphed.gov.in/arsenic/index.html) but its status is not clear and it lacks detail, thereby appearing to overestimate the lateral extent of the problem, and giving no information on its severity, which is patchy even at the village scale.

The effects, if any, of arsenic in groundwater on the health of livestock appears unknown and is never mentioned as an issue. More systematic investigations and reports, including publication of all data, are required to assess the extent or severity of the effects of arsenic on soils or crops in West Bengal.

2.3. Management options for monitoring and control

Options for Groundwater

Options for managing arsenic pollution of groundwater are well known and include, with commonness approximated in (parentheses):

1] rain-water harvesting (minor), 2] household arsenic removal filters (minor), 3] community removal filters (minor), 4] treatment of pond water aka pond sand-filters (uncommon), 5] deep private boreholes (> 150 m depth; not common), 6] deep community boreholes, often coupled to a rudimentary piped-water system (not common), 7] supply of treated surface water, typically via a rudimentary piped-water system (common in larger conurbations but rare in villages),

Choice of remediation/avoidance strategy should be site dependent. What works is usually what the local people buy into and are willing to accept/support. Deep boreholes are the most popular private option because it is a technology known to locals and one they have the knowledge to maintain. The PHED favours Option 7, and claims 65% coverage, but the basis of the claims is not known (population coverage?, area coverage?). Personal observations shows such schemes rarely reach small communities.

Options for Soils and Crops

The lack of restriction on groundwater pumping for irrigation in practice (it is supposedly licenced) limits options for managing and controlling arsenic pollution of soils by arsenic-polluted irrigation water drawn from the shallow groundwater. Given the large volumes of water needed for irrigation (0.5 to 1 m of water per year for Boro rice), the only viable control option is to exploit the low-arsenic deep aquifer for irrigation rather than use the arsenic-polluted shallow aquifer. This approach has been used by the State Water Investigation Directorate (SWID) of West Bengal since the 1960s on an industrial scale using deep boreholes and buried-pipe systems for irrigating large fields through gravity flow (the policy was fortuitous and not designed to avoid arsenic). The arsenic issue arises because farmers beyond the limit of the gravity feed install their own shallow diesel-pumped wells and invariably do so at shallow depth in arsenic-polluted aquifers. Options for control are either subsidy to farmers who convert to deep wells, or the introduction of regulation to limit irrigation pumping from shallow arsenic-polluted aquifers.

2.4. Research needs

Groundwater

Pollution by arsenic and fluoride occur through simple chemical reactions between minerals and groundwater that have been known about and studied for decades. Fine details remain to be evaluated but have little relevance for evaluation of risk to human health or soils. Research on the arsenic pollution of groundwater therefore needs to focus on understanding the controls on the patchy, indeed fractal, spatial distribution of arsenic in groundwater can be used to provide a rigorous scientific basis for aquifer remediation and development.

The following research needs were identified:

- Detailed and accurate maps of the spatial distribution of arsenic in groundwater, both laterally and vertically across West Bengal as a basis for planning remediation.

- As a further basis for planning remediation, detailed and accurate maps of the subsurface geology/sedimentology of the aquifers of West Bengal because that geology is a main control on the distribution of arsenic in groundwater.
- Modelling of groundwater flow at scales from local to basinal, so as to predict the movement of pollutants in groundwater caused by pumping for irrigation.
- Based on the above, the development of a management strategy based on local preferences for remediation and avoidance coupled to expert assessment of the most suitable site-specific option e.g. rainwater harvesting, or deep groundwater, or other options to include:

1. Long-term monitoring of water quality early diagnosis of potential problems e.g. use of sentinel wells to inform of impending breakthrough of arsenic to the deep aquifer, and into areas currently free of arsenic;
2. Formalization and support of community-based participatory management.

Soils and crops

The effect of arsenic pollution of soils on crops has been studied in detail in the USA and to a lesser degree in other countries. The research needs regarding soils are therefore focussed on ascertaining the scale and intensity of the problem, so that remedial action can be undertaken to limit or reverse arsenification of soils.

The following research needs were identified:

- Accurate maps of the subsurface geology/sedimentology of the aquifers of West Bengal because that geology is a main control on the distribution of arsenic in groundwater.
- Accurate maps of the distribution of arsenic in groundwater that is used for irrigation
- Assessment at a village level of how long arsenic-rich water has been used for irrigation and whether arsenic is accumulating in soils.
- Given the wide range of soil-types in West Bengal, a knowledge of what controls at a local level the accumulation of arsenic in soils e.g. length of flooding period, the amount of soil organic carbon or cropping patterns etc.

2.5. What data/tools are needed to provide supporting analysis options?

A principal need is for the multiple agencies in India to place in the public domain all the data they possess pertaining to aquifer geometry, the distribution of arsenic in groundwater, soils classification, and health effects pertaining to arsenic. Such an approach requires a serious and long-term effort by senior managers in government and its agencies to change the culture surrounding ‘ownership’ of government data – that it belongs not to the individuals that collect it, nor to the agencies that compile it, but to the people who pay for it through their taxes viz. the public. Whilst provision of data held by government and its various agencies is an aim of the National Hydrology Project, we note that the current ‘Project’ is the third such one, and that the previous two have little to show for their expenditure.

To supplement the above, concerted efforts should be made to tap the reservoir of local knowledge held by drillers, who know well the sediments of their areas of operation, even though few realise the significance of what they see and know from their drilling experience in terms of arsenic pollution.

3. Sewage reuse for aqua-farming

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3.1. Background information

East Kolkata Wetlands (EKW)

Presently, the total area of the wetland is 12,500 ha, among which there are 364 sewage-fed fisheries (5852 ha), agriculture (4781 ha) and solid waste farms (603 ha) and some built-up areas for human settlements (1326 ha). Local people in and around the East Kolkata Wetlands (EKW) is exclusively dependent on this sewage fed fisheries which contributes a substantial portion of fish demand in the city of Kolkata. East Kolkata Wetlands have been recognized as ecologically sensitive areas and named as Wetland of International Importance under the Article 8 of the Ramsar Convention; site number 1208.

As early as 1690, the managers and planners of Kolkata selected the eastern part of Kolkata as a reservoir of both liquid and solid wastes discharged by the city to save the Hugli River from receiving those wastes. There is an enough restructuring of wetland networks during the last 5 years. Overall report of the environmental impact assessment on East Kolkata Wetlands is positive.

On an average 600 Million liters per day (MLD) of the city sewage reaches the East Kolkata Wetlands (EKW) where it undergoes semi-natural attenuation process in the bheries (fish rearing ponds, there are all total 364 operating bheries in EKW) followed by draining into Bidyadhari river, which is an estuarine tributary of River Hooghly. Sewage arriving through the canal connected to the Bantala pump house is released into the bheries. Approximately

450 MLD of sewage is fed to the bheries for fish cultivation and alternatively natural attenuation whereas the rest is directly discharged into Bidhyadhari river. Bheries can accommodate about 18,800 litres of wastewater per seconds (lps) in the existing 4400 ha of sewage-fed fisheries. Gradually, within a few days the wastewater and content of the organic compounds undergo biodegradation. In the fish ponds the quantum of organic load ranges from 20 to 70 kg per ha per day.

Bheries are mostly run by cooperative society organisations, though a few privately owned small bheries also do exist.

CFCS Limited

Chorchoria Fisheries Cooperative Society Limited (CFCS) is one of the most flourishing organisations in fish production using city sewage. It owns 6 bheries comprising of approximately a total of 400 acres of area. They claim to have been awarded by the national as well as state government for the highest annual fish production in the year 2008 and 2015 respectively. Bheries owned by CFCS are situated in Bamanghata where approximately 90% of the population is dependent upon cultivation and sale of fish. Bamanghata situated in the district of South 24 Parganas, comprises of 5 moujas namely Hadia, Hatgachha, Jotbhim, Kochpukur and Dhapamanpur, out of which 3 (viz. Hadia, Hatgachha and Jotbhim) are within the EKW region. Total population of Bamanghata is approximately 30000. The CFCS Ltd. has been recently sanctioned a grant of 19.34 crores by the state government in the year 2018 for upgrading the bheries infrastructure. Canal cutting and land digging work is supported by West

Bengal State Fisheries Development Corporation Limited (WBSFDC).

Process of fish rearing

CFCS purchase the hatchlings from a fish hatchery in Bankura, West Bengal. Hatchlings are initially nourished in small ponds with artificial nutrients and not at all fed with sewage. Sewage rich in nutrients, nitrates and phosphates help in phytoplanktonic boom in the bheries within 4-7 days based on availability of sunlight. Once the bheries are fully green with phytoplanktons, pre-acclimated (fed with diluted sewage) hatchlings are released into the bheries for growing and surviving by feeding on the phytoplanktons. Once the fishes attain the desired size, they are released into the large bheries which are fully fed with planktons grown on sewage water. Bheries have a depth of 7-8 feet and a sludge retention time of estimated 25-30 years. Clean water is released from outlet end of the bhery, which is occasionally used for irrigating crops or else is drained into Bidhyadhari river. In general the average sewage water retention time in each bhery is approximately 15 days. Five to 1000 kgs of fish (Mrighel, Catla, Bata, Tilapia, Lailontika, etc.) are caught every day and the entire process goes on continuously.

Hatchling rearing ponds are cleaned at regular intervals to sustain the health of the hatchlings. Water is completely pumped out and the floor of the pond is treated with indigenous solution comprising of lime, caustic soda and alum. During the monsoon season when the nutrients load in the sewage is low and phytoplanktonic growth is hampered, artificial fish feed prepared from cheap sources, for example seed coats of mustard and mahua, is used in the bheries. There are instances of fish deaths during winter and spring which may be due to generation of acidity arising from accumulation of high BOD and low DO in the bhery. As a remedial measure 500 - 600 kgs of lime are deposited into the bhery to raise the pH and DO level.

3.2. Nature and Magnitude of the issues

Direct use of sewage water, without any treatment, can result in accumulation of contaminants and bio-accumulation in fish. There are a number of tannery industries in the vicinity of the EKW. Though tannery effluents are not released into the EKW, chances of tannery effluents contaminating the city sewage inflow through runoff during the monsoon cannot be ignored and can result in heavy metal pollution. Besides, the presence of persistent organic pollutants (PCBs, pesticides, pharmaceutical products etc.), nano-materials and micro-plastics (especially with many plastic recycling units seen around the area) in the sewage cannot be ruled out; neither can the potential bio- accumulation in the cultivated fish (approximately 500kgs/day), which are distributed across many Kolkata markets, be ignored.

Vegetables and plants like spinach, potato, cauliflower, etc. and herbal plants like tulasi (Ocimum, figure 1) reported to be grown using sewage water in an around wetland area might accumulate above mentioned contaminants.

Figure 1: Tulasi (Ocimum) cultivation noticed at EKW

Due to un-regulated use of antibiotics in Kolkata, the untreated sewage can be laden with antibiotics resulting in EKW a unique host for antibiotic resistant bacteria causing widespread AMR.

It was also noted that people of the village mostly rely on groundwater extracted from the borewells for drinking and cooking. Packaged drinking water is also used in the area based on the economic level of the people. There have been some reports of arsenic contamination in the region however no visible health issues were noted.

There have been reports of dip in the visit of migratory birds in the EKW region over the years.

Acceleration of urbanization and increase in population density is a major issue which has started to put pressure on EKW and therefore the sustainability of the EKW is at risk if no mitigation or adaptation measures are identified and deployed.

Large tourism activities can also pose a threat to these sites as wetlands are known to be very sensitive and fragile ecosystem.

3.3. Potential impacts

Chronic health effect in Kolkatans

Presence of any potential pollutant in fish and vegetables will pose threat to human health and result in food chain contamination, they can also effect the fish (changes in fish anatomy). Even though the metal contamination may be below the permissible limit in a fish when measured at a point of time, many heavy metals are non-biodegradable and can accumulate along the food chain causing human health risk.

Effect of tourism on EKW ecosystem

Tourism might result in human intervention in these wetland areas, which will bring many types of pollutants such as plastics, polythene, vehicular exhausts etc. and will further degrade the area, disturbing both flora and fauna of the area. The disturbance arising due to human intervention in wetland area will further decline the bird population.

Restrictions of activities in wetlands — under Wetlands (Conservation and Management) Rules, 2017 there are certain restrictions of activities in wetlands, which are as followed

1. The wetlands shall be conserved and managed in accordance with the principle of 'wise use' as determined by the Wetlands Authority.
2. The following activities shall be prohibited within the wetlands, namely,-
    i. Conversion for non-wetland uses including encroachment of any kind;
    ii. Setting up of any industry and expansion of existing industries;
    iii. Manufacture or handling or storage or disposal of construction and demolition waste covered under the Construction and Demolition Waste Management Rules, 2016; hazardous substances covered under the Manufacture, Storage and Import of Hazardous Chemical Rules, 1989 or the Rules for Manufacture, Use, Import, Export and Storage of Hazardous Micro-organisms Genetically engineered organisms or cells, 1989 or the Hazardous Wastes (Management, Handling and Transboundary Movement) Rules, 2008; electronic waste covered under the E-Waste (Management) Rules, 2016;
    iv. Solid waste dumping,
    v. Discharge of untreated wastes and effluents from industries, cities, towns, villages and other human settlements;
    vi. Any construction of a permanent nature except for boat jetties within fifty meters from the mean high flood level observed in the past ten years calculated from the

3.4. Management options

Sewage-fed fish culture is a biological means of waste water treatment. Here we describe several management options to ensure the long term environmental sustainability and associated human health benefits of fish production.

A summary of the management options discussed by WGIII and stakeholders are as follows:

1. End to end stakeholder engagement: Management and maintenance protocols must be fit for purpose, culturally acceptable, cost effective, and realistic to achieve. Stakeholders discussed engagement with Social Help Groups that include members of the local community, panchayat etc. Whilst this was encouraging, the community was only consulted on the project after the design and construction phasewhich is far from ideal. Effective and transparent communication between all interested parties (people on the ground, regulators, academics etc) is encouraged from the project inception, build, adoption and post construction phase.
2. Integrated Monitoring Framework: The composition of waste entering ponds in recent decades has changed with the introduction of industrial effluent to the relatively harmless domestic sewage. To assess the long-term effectiveness of fish ponds requires a comprehensive sampling protocol of environmental (sewage effluent, water quality, sludge accumulation/composition) and fish health (tissue, liver etc) metrics over time. Little is known about the impact of the monsoons on environmental quality. Stakeholders spoke of the necessity of fish food supplements due to the dilution of waste in the ponds during the monsoon season. Regular monitoring(in space and time) to establishbaseline conditions are essential to assess the performance of the pond system and the effectiveness of future interventions (e.g. separation different source of waste before entry to the pond system to reduce the impact of heavy metal contamination).There is also a recommended that laboratories are assessed in term of accreditation to meet QA/QC criteria and that laboratories can handle routine analysis (Ecoli/heavy metals) and have the capability for analysing emerging contaminants (pesticides, micro plastics) in environmental samples and in the food chain.
3. Maintenance: Ponds are drained during the dry season to treat accumulated sludge (quick lime/salt).
4. All management options require an assessment of the social and cultural implication and most importantly need to be cost-effective. Incentivisation schemes were discussed to encourage women and younger population to stay in rural areas to manage the waste treatment and aquaculture to ensure a sustainable livelihood/practice.
5. Wider benefits: Ideally plans for a tourism strategy etc should take place before the design phase of the pond system to ensure that basic needs are met from the system. i.e. enhance access to the ponds, biodiversity (move away from rectangular pond design to more natural systems), facilities for tourist (including waste management plan…beyond just sewage) etc.

3.5. Data/Tools

In line with above mentioned issues and management options identified by the group, following data should be made available both for research and public knowledge

1. Regularly monitored data on contamination profile of sewage water entering the wetland and the treated water leaving the wetland
2. Comparison of water quality against Indian standards and international standards
3. Temporal and spatial data on fish quality produced in this wetland

Integrated monitoring framework; remote sensing tools for wetland coverage, environmental and health risk assessment, ecosystem service management are some of the tools, we think that could be used to address the issues and management options identified for protection and wise use of wetlands as defined by Ramsar.

3.6. Research Needs

Two-way discussions between stakeholders and scientists highlighted several areas for further investigation.

1. An impartial review of existing monitoring records/regulation to establish a robust baseline of chemical and biological metrics and a review of evidence against the existing standards. A potential challenge for UK: India Partnership is the setting standards given that standards are more stringent in the UK. How to deal with international standards on international projects is a research question in its own right! Standards have also changed over time in India (i.e. the arsenic standard is becoming more stringent (50 ppb vs 10 ppb) further adding to the challenge.
2. Integrated monitoring framework (See point 2 above)).
3. When measured contaminants in fish exceed safe limits (do these exist?) what interventions/mitigations are available? If safe limits or critical loads have been established for heavy metal, similar limits are required for emerging contaminants.
4. More evidence is required on the chronic exposure (low concentrations over long periods) of contaminants on human / environmental versus acute exposure to inform new guidance on waste water treatment to safe guard human health and promote sustainable environmental management options.
5. Pond maintenance: The long-term effectiveness of lime and salts in the treatment of accumulated sludge in ponds is unknown. Wider literature on the maintenance of ponds highlights desludging (honey suckers) as a routine maintenance option and offsite disposal (generally into unregulated ditches). This practice is unsustainable and unacceptable and required further research.
6. Integrated assessment of environmental, social and economic systems. Wider studies on biodiversity indices/monitoring are proposed to assess change over time in areas dominated by fish ponds. For example, evidence is emerging that the migratory patterns of bird population have changed, although it is recognised that external drivers may influence such findings.

4. Fate, Transport and Remediation of contaminants

Dr Priyanka Jamwal, Dr Diganta Bhusan Das, Mr Sunil, Devendra Saroj, and Dr Rudra Kaylan

4.1. Introduction

Kolkata, the capital city of West Bengal, is one of the most important cities in eastern India. The core of Kolkata city is spread over around 200 square kilometres and has a population of 4.5 million people. Officially 15% of core Kolkata's water come from groundwater sources and the rest from surface water, with the entire city, excluding a newly added 25 square kilometre area in the couth, being supplied water through pipelines. In reality, up to 25% to 30% of the water used in households is groundwater.

The city generates 706 MLD of domestic sewage. Out of which 24% is treated and the rest flows untreated into river Ganga and the east Kolkata wetlands. Considering that river Ganga is used as a raw water source for drinking water, untreated effluents discharge poses a great risk to public health. Official data reports 108 MPN/100 ml of Faecal coliform (FC) levels in river Ganga. Also, the use of untreated sewage for fisheries has led to serious health concerns. The drinking water supply also gets contaminated by leaking sewerage pipes. Though the state pollution control board ensures that industries treat effluent before disposing it into the sewer line reports suggested that the industrial pollutants including heavy metals also leak into groundwater and surface water supplies.

Given the extent of pollution problem and lack of space to build the centralised sewerage systems, Group -4 at the Indo UK workshop suggested a decentralised approach to address the water quality issues in the rapidly growing regions. The group considered a framework to a) understand the fate and transport of contaminants in the surface and groundwater and b) suggest technical/social interventions to reduce risk to public health (see Figure 1).

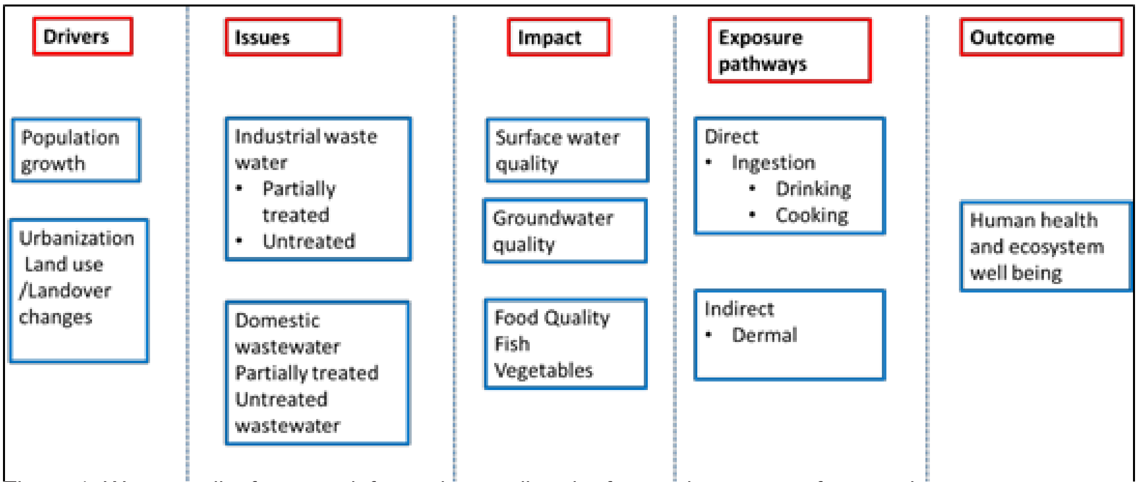

Figure 1: Water quality framework for understanding the fate and transport of contaminants

The team proposed to generate primary data on the water quality primary data on water quality, food quality and human and ecosystem health and use existing water quality and health risk models for scenario building and predictions. For effective implementation of decentralized systems for wastewater treatment, the group suggested generation of primary and secondary data on the following:

4.2. Research and data needs

Data (water quality, wastewater generation, flow data, human health data)

In order to develop the proposed system a large amount of data is required. There is already some data available and therefore any gap in these data should be done. In general, the physical parameters are useful in knowing the characteristics of water without further sophisticated analysis. The physical parameters are mainly measures of aesthetics. For example, all substance suspended in water qualifies to be suspended solids. Significant concentration of suspended solids was visually observed. Similarly, turbidity is an issue. Turbidity is the measure capacity to scatter/absorb light by suspended solids in water. It is contributed by both suspended solids and colloidal material in water. Most of turbidity in surface water is due to the erosion of colloidal substance like clay, silt, rock fragments, microbes etc. Colour of the water (grey) was visually observed as well. It is commonly present in surface water due to absorption of colour released by humus substance. Apart from humus, presence of algae, soil particle and reflection of environmental setting contributed to water bodies. Besides these there is a need for accurate local data on wastewater generation rate and population (both historical and current data).

Application of modelling tools for detailed scenarios analysis and predictions could be useful. For example, application of numerical tools to analyse mass transport and fluid flow in the channels should be carried out to accurately relate these behaviours to various channel characteristics.

Optimization of implementation and design of decentralized treatment systems. We intent to use modelling tools along with the water quality data, hydrology data to identify the location and optimum number of decentralised treatment system required to attain treated water instream before it is discharged into the river Ganga.

Community engagement for sustainability of these systems is needed. Now, there is no such system in the locality. Whether such a system is needed or should be analysed in detail for which community engagement will be crucial.

Integration with the national water policy. After demonstrating the impact of the decentralised approach in addressing the water quality issue, we intent to integrate the same with the national water policy. We propose this approach to address issues related to both point and non-point sources of pollution.

4.3. Catchment based management approach (Technical intervention)

The major part of the pollutants originating from municipal sector are difficult to control as much as the industrial pollution. It is recognised by the West Bengal State Pollution Control Board that municipal wastewater sector is currently the major challenge, even though the industries have generally been perceived as the common polluter to the surface water (e.g. the Hooghly River). In a large catchment it is particularly a challenge to tackle the pollution from municipal wastewater resulting in the deterioration of water quality, e.g. the indication of 108 MPN/100 ml of faecal coliform (FC) in the Hooghly River, making it not suitable for meeting the bathing standard).

The municipal wastewater sector is diverse, with some centralised wastewater treatment plants connected to the network of large sewerage in Kolkata, similar to other large cities. However, a large volume of wastewater reached the surface water bodies, e.g. Hooghly River, via many small drains, with a large fraction being directly discharged without any treatment. The drinking water treatment plants are located downstream to the discharge points for municipal sewage drains, and they need to be designed to treat highly polluted river water mixed with untreated municipal sewage.

The development of a modern centralised sewerage network and connection to large centralized wastewater treatment required massive financial investment, but more importantly seen as long-term infrastructure project (paternally decades of slow and continuous development process). Therefore, decentralised technological interventions may play important role in managing a catchment is short term. Decentralised systems can be tested according to the concept shown in Figure-2. Such systems can be applied as small treatment units locally to provide clean water for reuse or just for treating the wastewater. Also, in-drain treatment systems can be tested, which may provide an alternative to a separate area required for building a treatment system. Such ideas are evolving and further studies, involving real field trials will provide systematic data and experience for addressing the problem of municipal wastewater in Kolkata.

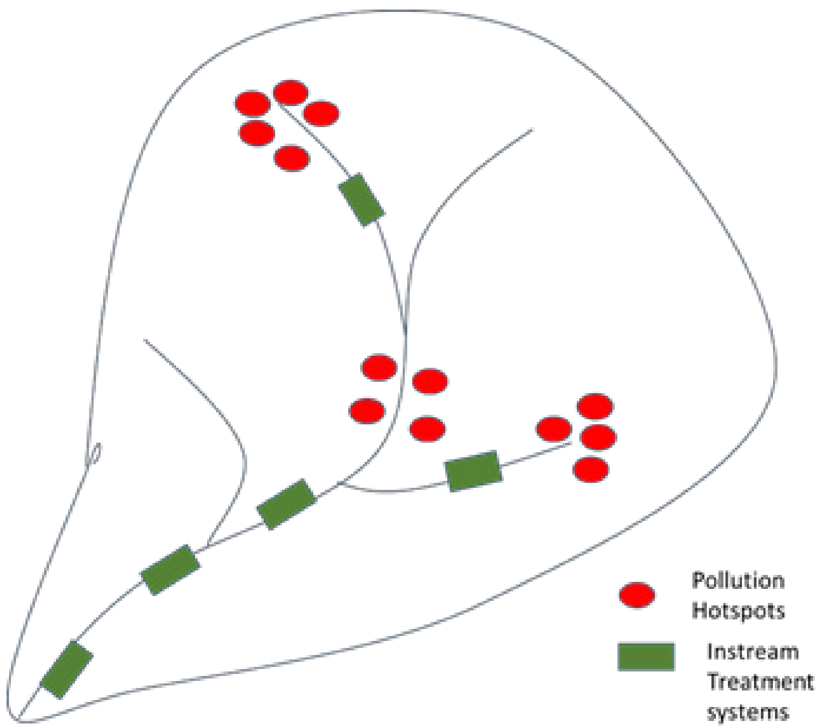

Figure 2: An example of catchment management intervention through decentralised in- drain sewage treatment

Back cover image: Kolkata, India (Photo credit Emma Bennett, IUKWC)

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