STI 2018 Leiden

23rd International Conference on Science and Technology Indicators
"Science, Technology and Innovation Indicators in Transition"

STI 2018 Conference Proceedings

Proceedings of the 23rd International Conference on Science and Technology Indicators

All papers published in this conference proceedings have been peer reviewed through a peer review process administered by the proceedings Editors. Reviews were conducted by expert referees to the professional and scientific standards expected of a conference proceedings.

Chair of the Conference

Paul Wouters

Scientific Editors

Rodrigo Costas
Thomas Franssen
Alfredo Yegros-Yegros

Layout

Andrea Reyes Elizondo
Suze van der Luijt-Jansen

The articles of this collection can be accessed at https://hdl.handle.net/1887/64521

ISBN: 978-90-9031204-0

Nanomaterials in Sewage Treatment for Cleaning River Yamuna from the Lenses of the Responsible Innovation

Swati Kumari

swati.antim@gmail.com
Centre for Studies in Science Policy, Jawaharlal Nehru University, New Delhi, 110067 (India)

Abstract

World over rivers, particularly in and around urban canters are facing severe threat of the 'pollution'. Though the river pollutions are highly specific to the cultural setting of the city, still driven by the technological fixes, at policy level, unrestrained faith is reposed in the capabilities of the technology. Such, untested faith in the technology marginalizes the innovative potential to address the environmental issues faced by the society. Interaction between the society and technology is nuanced phenomenon. Without due consideration of the 'risk & safety' and 'values', the responsible nature of both, technology as well as innovative process, comes under question mark. To study these nuanced and complicated interactions, this paper has selected river Yamuna in National Capital Region (NCR) of India as case study. After Failure of earlier programs to 'clean' the Yamuna in Delhi, Nanotechnology has been propagated at the policy level with certain claims regarding the potential of the nanotechnology. Objective of this study was to analyse the 'true potential' of nanotechnology to clean the river Yamuna in NCR. This paper has been divided into four parts. The first part is about the background of the case study which would reflect on the convergence of various problems associated with the river pollution in general and Yamuna in particular. The second part has discussed the adopted framework of the 'Responsible Innovation' and a need to broaden and implement the framework in case studies. The third part is focused on the method of the data collection and procedures adopted. Finally, the findings and conclusions on case study are discussed in fourth part.

Background

Water and sanitation both are part of the Sustainable Development Goals (SDG) and have direct mutually correlative relationship. It is in this context that rivers are the physical site where this relationship become objectively tangible. Due to convergence of various cultural, economical, technological and policy issues, cleaning of rivers is easier said than done. The case of the river Yamuna in NCR region is no different (Babu, Seth, Dixit, & Narain, 2007; Haberman, 2006; Misra, 2010). The problem of river pollution is even more complicated in India. In India rivers are revered as mother and Goddesses and have huge religious significance also. Various religious rituals are performed on the river banks. It is the biggest irony that a river is supposed to wash away all the wrong deeds, but itself left polluted by the devotees (Narain, 2004). Along with this occasional intensive 'ritual pollution', dumping of untreated sewage has been identified as major contributor to Yamuna's pollution load (Goel, 2006). Further recent water profile studies has brought out the presence of the heavy metals in the Yamuna (Christopher, Kaur, & Singh, 2012; Malik et al., 2014). Starting from 1985, Governments response in this regard has been bringing up the Yamuna Action Plan (YAP), with focus on building of the large Sewage Treatment Plants (STP). This approach has largely failed to deliver on desirable objective of 'clean Yamuna' (Akiba et al., 2015; Cieślik, Namieśnik, & Konieczka, 2015; Gani, Ali, Rajpal, Jaiswal, & Kazmi, 2016; Okubo et al., 2015; "Privatizing Sewage Treatment Systems in Delhi," 2013). In such a scenario nanotechnology, has been proposed as an innovative solution for cleaning rivers. At the policy level, it is proposed that, 'nanomaterials can be used in the sewage treatment for achieving the high efficiency and efficacy. Research work is going on in the institutions for developing such nanomaterials. However, there are limitation and potentials hazards are attached to the liberal use of the new technology in the open environment (Ali & Sinha, 2015), this has been discussed in the later part of the paper. At deeper level without public participation and features of the accountability & sustainability, this is akin to the 'technological fixation'(Barami & Center, 2003). Therefore we need better inbuilt ethics in the new technologies for innovating responsible (Moor, 2001). There is need of assessing the use of nanomaterials for cleaning the river Yamuna from the responsible innovations perspective.

Responsible Innovation

Technological innovations are often hastily considered as quick fixes for dealing with issues by the policy makers. But with implementation of the new technology new issues also emerge. In fact, not only the technology itself but the process of its implementations remains black boxed. The is paradoxical in the way that new innovations are implemented for the development, but the participation of the stakeholders, values and cultural factors are not considered while formulating and implementing the policies. Similarly, there is issue of the 'sustainability' need to be looked thoroughly while brining technological interventions. Further this sustainability has to encompass both economic and environmental sustainability. Therefor in the innovation studies, the responsible innovation framework has emerged out.

In the past decade, the responsible innovation fast emerged as the frame work for analyzing the application of new emerging technology at the societal interface. At the same time at the policy level also the responsible innovation framework has acquired quite significance (Owen, Macnaghten, & Stilgoe, 2012). Although the responsible innovation concept developed more than a decade ago, yet new dimensions keep adding to the framework as the theoretical background is maturing in the light of the society, technology and environmental interactions (Armstrong et al., 2012; Guston, 2004; Hellström, 2003; Lee, 2012; Von Schomberg, 2007). The latest emerging themes within the responsible innovation includes, democratic governance of the innovation process, right impact of the innovation process, as well as the responsiveness of the innovation process.

In the developing countries, objective of the innovation is largely constituting the eradication of poverty and underdevelopment. As result a theoretical framework with features responsive to such needs of society is needed. Therefore in the context of the developing countries a responsive innovation framework essentially includes key dimensions such as- Anticipation, Reflexivity, Deliberation, Responsiveness and Participation (Singh & Kroesen, 2012). These five dimensions enables the sustainability analysis of the new technologies. Here it must be noted that sustainability to be effective and practical includes social, economic and environmental sustainability (Koops, n.d.). Anticipation emphasizes on the 'foresight' for different aspects of the innovation including the possible impacts. Such foresight shall help in innovation process, adaptation, and diffusion of the innovations. Such an exercise is also important for minimizing the risk associated with the implementation of new technologies, as a result providing higher ethical credibility to the new technologies (Hoven, 2014). The dimension of the reflexivity correlate with the empathetic understanding of the cause and effects. Here for a broader perspective 'influences' are also taken into account (Owen et al., 2012). All these dimensions of responsible innovation framework provided the suitable analytical framework to assess the application of the nanotechnology for cleaning the river Yamuna in Delhi.

Social acceptability of the technology is crucial to solve the problem of, flow of untreated waste water to the Yamuna in Delhi. For instance, acquiring land for construction of large STP in the heart of the city is next to impossible. The practical reasons like health, safety, foul stench and ideological reasons of 'purity & pollution', both plays considerable part in social acceptability of the technology. Therefor to capture these dimensions there is need to explore the issues such as 'trust', 'social accountability of policy' etc. to broaden the ambit of the responsible innovation framework. It is in this context the hope offered by nanotechnology for tackling river pollution has been viewed by this study from the lenses of 'responsible innovation'.

Method & Procedure

River Yamuna in the NCR of Delhi has been selected for the case study. Survey method was adopted for collecting information pertaining to Government agencies, Companies, Research Institutions and STPs engaged in development and implementation of new sewage treatment technologies. Survey of the existing literature on nanotechnology in sewage treatment and policies were also done. Purposive sampling method was used for selecting among these for conducting the in-depth face to face semi-structured interviews of total 75 persons, for collection of the primary data. Three Focused Group Discussion of the experts in the field were also conducted on the important aspect of the 'risk & safety' of nanomaterials. This qualitative data has been transcribed and further analyzed for policy inputs.

Finding & Conclusion

The advocates of the technology which usually belong to the scientific community emphasize that 'to every problem there exist a technological solution'. This high level of the technological optimism has been severely criticized by the other group of environmentalist. This group argues that such 'technological fixations' have given freehand to the unbridled exploitation of the environment (Barami & Center, 2003; Brownsword & Yeung, 2008; Sarewitz & Nelson, 2008). However in-depth analysis of the technology is capable of addressing these concerns. Therefore, use of nanomaterials has been analyzed on the yardstick of, anticipation, reflexivity, deliberation, responsiveness and participation. It is in this context nanomaterials have not only advantages and disadvantages but also technical hurdles in application. This brought us to the question of the economic, social and environmental sustainability of nanomaterials in open environment.

Advantages of nanomaterial arises from the material property. Due to high specificity, it can help in removing heavy metals selectively. Similarly, at lab experiments it was found to enhance the efficiency of the STP, which is crucial for reducing the power bill as well as the size of the STP. Thus, use of nanomaterial can help in overcoming policy hurdles as acquiring large land in the middle of city like Delhi is almost impossible. On the other hand, there are disadvantages such as, sewage have broad spectrum pollution load whereas nanomaterials are highly specific.

There are issues regarding the **economic sustainability** of the synthetic nanomaterials for sewage treatment. Application of a new technology needs a strong return on investment model. The sewage treatment in Delhi does not have specific revenue generation models. There is no charge levied specifically for the waste water treatment. As a result, the cost effectiveness of a technology is critical for its adoption. The synthetic nanomaterial is more active and efficient but the high cost is the biggest hurdle in its deployment in STPs. The table1 has brought out the comparison between the properties of the natural and synthetic nanomaterials.

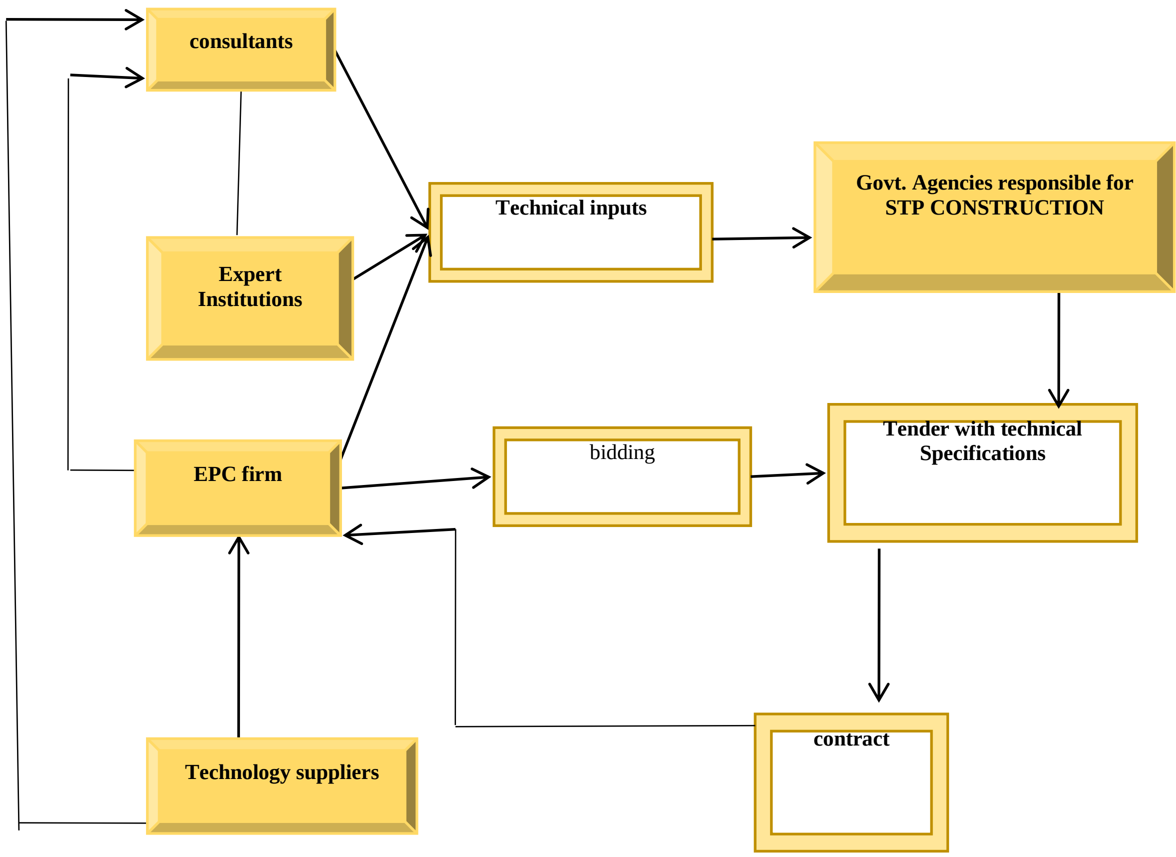
Table 1: *Comparison between Natural and Synthetic Nanomaterial*

	Nanomaterial		
Comparison Parameters	**Natural**	**Synthetic**	**Comments**
Cost	No designing and Synthesising cost, only processing cost.	High	1 mg of synthetic nanomaterial cost between Rs. 4000-5000 as the prices of the major nanomaterial supplier Sigma, Rentier. The natural nanomaterials are present in the environment and required only marginal processing cost.
Stability	Robust	Vulnerable to the change in the atmospheric conditions	
Activity	Largely remain unaffected with the change in season	The seasonal variations have impact.	
Risk	Predictable	Not Researched	The natural nanomaterials are not specific to the pollutant i.e. difficult to target the heavy metals.
Target Binding capacity	Not specific	Very high specificity	
Flexibility on inclusion of the desired properties	Very less	Very high	
Action Spectrum	Broad	Narrow	

Source: *Compiled from the Interviews*

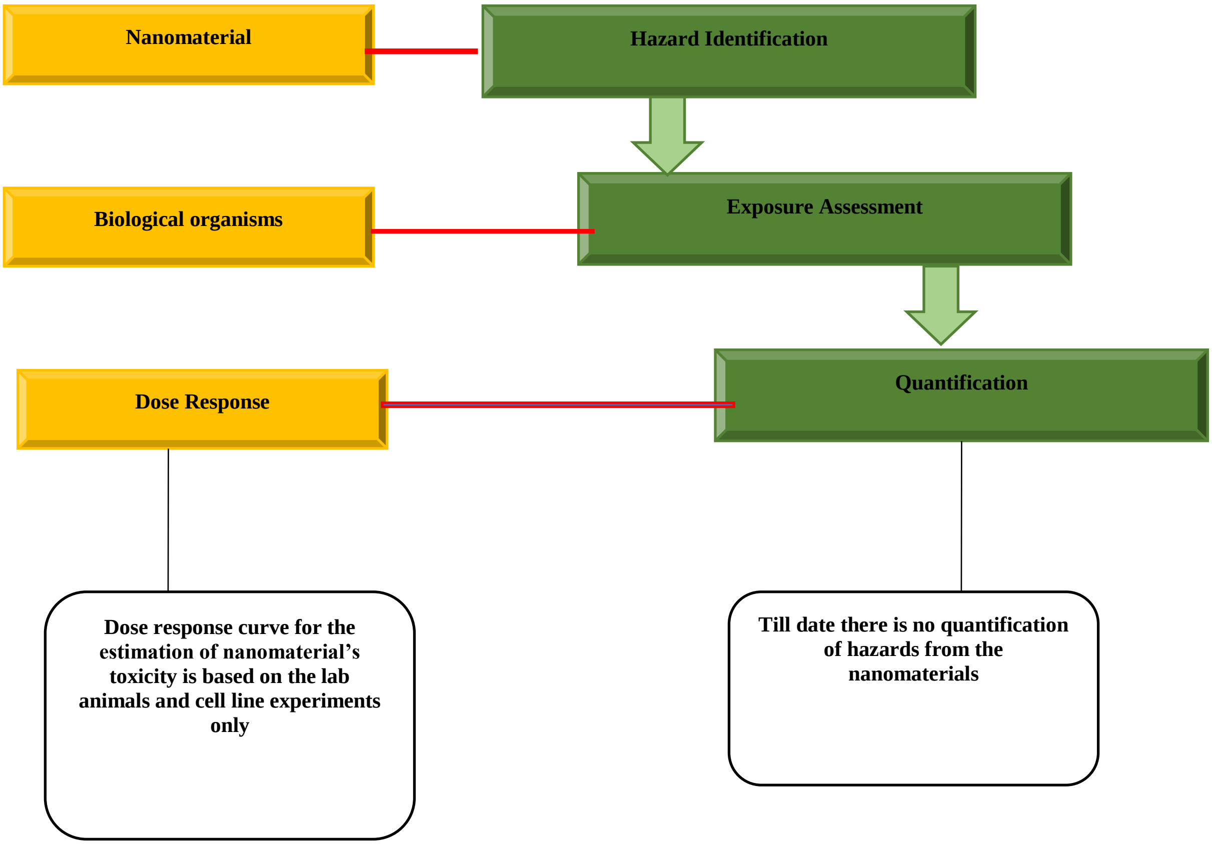
At the policy front, also, there are issues of the responsiveness, participation and accountability. There is complete policy vacuum over the use of the synthetic nanomaterials. Similarly, despite wastewater being the mammoth problem there is no specific policy to deal with the sewage treatment. The commercial process is still following the traditional tender process. Firms were particularly resentful of the 'consultant' to government which according to them act as 'iron curtain' and blocks the new innovations to come into the market. There for the 'competition' remains highly skewed, which is detrimental to investment in the field. Figure b has brought out the complicated commercial process which demotivates the openness and participation.

Figure b: *Diagrammatic Presentation of Commercial Process*



The **risk & safety analysis** is done for checking **environmental and social sustainability** of the synthetic nanomaterials. The technical definition of the risk includes prediction of the impacts, management and control of such impacts through the expert institutions and policy regulations. However, this narrow technical definition of the 'risk' has been criticized in the social sciences. In the framing of the technical issues it is assumed that public are equally ware about the associated technological risks, hence the challenge for the public policy is that of making people aware and communicating risks in the rational terms (Melissa leach, Scoons, & Wynne B., n.d.). This has led the scientific and policy institutions frame 'risk' as calculable probabilities of known outcomes, which is in fact can be seen as uncertainty or even ignorance about the probable consequences of a technological adoption.

Figure c: *Steps in Hazard Analysis of the Nanomaterials*



Ethical Risk Analysis: Responsiveness. Technology does not operate in vacuum; rather it is embedded in the socio-cultural context. The adoption of a new technology is a challenging task not only from the technological and policy perspectives, but ethical issues are equally important. Generally, many adverse impacts of a technology became apparent after a long time. For the natural nanomaterials, human body is well adapted, but the impacts of the synthetic nanomaterials are not precisely known. At present, there are no guidelines for the use of the nanomaterials in India. In such a situation, a person is exposed to nanomaterials from variety of products. The use of the synthetic nanomaterials in the waste water treatment will enhance the quantum of exposure many folds. The application of a technology without wide ranging consultations is not prudent.

Issue of water has huge significance in the sustainable development discourses. There is huge scope of the further research in the field, in terms of both theory and practice. more comparative studies will enrich the understanding for innovating responsible for sustainable dealing with river pollutions specifically around urban centres.

References

Akiba, M., Senba, H., Otagiri, H., Prabhasankar, V. P., Taniyasu, S., Yamashita, N., … Joshua, D. I. (2015). Impact of wastewater from different sources on the prevalence of antimicrobial-resistant Escherichia coli in sewage treatment plants in South India. *Ecotoxicology and Environmental Safety*, *115*, 203–208.
Ali, A., & Sinha, D. K. (2015). Policy on Risk Governance for Nanotechnology Development in India, 9.
Armstrong, M., Cornut, G., Delacôte, S., Lenglet, M., Millo, Y., Muniesa, F., … Tadjeddine, Y. (2012). Towards a practical approach to responsible innovation in finance: New Product Committees revisited. *Journal of Financial Regulation and Compliance*, *20*(2), 147–168.
Babu, S. S., Seth, B. L., Dixit, V. K., & Narain, S. (2007). *Sewage Canal: How to Clean the Yamuna*. Centre for Science & Environment.
Barami, B., & Center, V. (2003). Technology Fixes for the New Global Risks: Do they Address Asymmetric and Non-linear Threats?'. *Logistics Spectrum*, *37*(1), 14.
Brownsword, R., & Yeung, K. (2008). *Regulating technologies: Legal futures, regulatory frames and technological fixes*. Bloomsbury Publishing.
Christopher, D., Kaur, S., & Singh, R. (2012). WATER QUALITY STATUS OF RIVER YAMUNA IN DELHI WITH REFERENCE TO PRESENCE OF HEAVY METALS: A REVIEW, 6.
Cieślik, B. M., Namieśnik, J., & Konieczka, P. (2015). Review of sewage sludge management: standards, regulations and analytical methods. *Journal of Cleaner Production*, *90*, 1–15.
Gani, K. M., Ali, M., Rajpal, A., Jaiswal, H., & Kazmi, A. A. (2016). Sewage treatment efficacy and heavy metal removal in moving bed biofilm based treatment plants of northern India. *Journal of Water Sanitation and Hygiene for Development*, *6*(1), 115–120.
Goel, P. K. (2006). *Water pollution: causes, effects and control*. New Age International.
Guston, D. H. (2004). Responsible innovation in the commercialized university. *Buying in or Selling Out*, 161–174.
Haberman, D. (2006). *River of love in an age of pollution: The Yamuna river of northern India*. Univ of California Press.
Hellström, T. (2003). Systemic innovation and risk: technology assessment and the challenge of responsible innovation. *Technology in Society*, *25*(3), 369–384.
Hoven, V. den J. (2014). *Responsible innovation 1: the ethical governance of new and emerging technologies*. New York: Springer.
Koops, B.-J. (Ed.). (n.d.). *Responsible Innovation 2: concepts, approaches, and applications*.
Lee, R. G. (2012). Look at mother nature on the run in the 21 st century: responsibility, research and innovation. *Transnational Environmental Law*, *1*(1), 105–117.
Malik, D., Singh, S., Thakur, J., Singh, R. K., Kaur, A., & Nijhawan, S. (2014). Heavy Metal Pollution of the Yamuna River: An Introspection, 8.
Melissa leach, Scoons, I., & Wynne B., B. (n.d.). Science, Citizenship and Globalization. In *Science and Citizenship: Globalization and the Challemges of Engagement* (1st ed., pp. 4–15). U.K: Cambridge University Press.

Misra, A. K. (2010). A river about to die: Yamuna. *Journal of Water Resource and Protection*, *2*(05), 489.
Moor, J. H. (2001). Why We Need Better Ethics for Emerging Technologies. In J. van den Hoven & J. Weckert (Eds.), *Information Technology and Moral Philosophy* (pp. 26–39). Cambridge: Cambridge University Press. https://doi.org/10.1017/CBO9780511498725.003
Narain, S. (2004). Why the flush toilet is ecologically mindless and why we need a paradigm shift in sewage technology. *Ecosan–closing the Loop*, 11.
Okubo, T., Onodera, T., Uemura, S., Yamaguchi, T., Ohashi, A., & Harada, H. (2015). On-site evaluation of the performance of a full-scale down-flow hanging sponge reactor as a post-treatment process of an up-flow anaerobic sludge blanket reactor for treating sewage in India. *Bioresource Technology*, *194*, 156–164.
Owen, R., Macnaghten, P., & Stilgoe, J. (2012). Responsible research and innovation: From science in society to science for society, with society. *Science and Public Policy*, *39*(6), 751–760. https://doi.org/10.1093/scipol/scs093
Privatizing Sewage Treatment Systems in Delhi. (2013), 39.
Sarewitz, D., & Nelson, R. (2008). Three rules for technological fixes. *Nature*, *456*(7224), 871.
Singh, R., & Kroesen, O. (2012). Understanding responsible innovation from developing countries perspectives. In *The 2nd conference on responsible innovation 2012*.
Von Schomberg, R. (2007). From the ethics of technology towards an ethics of knowledge policy & knowledge assessment.