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A Statistical Approach on the Economics of Sustainable Household Waste Management in Mumbai

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Abstract: **The scenario of Tragedy of Commons was narrated by English Mathematician and Economist William Forster Lloyd, in 1833. This research paper relates household waste management in Mumbai to the Tragedy of Commons. In 2016, the Ministry of Environment revised Solid Waste Management Rules, whereby it mandated segregation of waste at source to turn waste into wealth by 'recovery, reuse and recycle'. These new rules make waste management the responsibility of the waste generator so that it can be handled in an efficient, decentralized manner without overburdening the limited public resources and infrastructure. In this paper, an investigation has been done of how the scenario of Tragedy of Commons is applicable despite all these rules, and how people end up 'fouling their own nest'. This paper proposes improved ways for sustainable household waste management. The major discussion of this paper is on the environmental, economic, and health benefits of composting organic waste and recycling plastic waste from the HW.**

Key wordss: **Tragedy of commons, MSW- Municipal Solid Waste, HW: Household waste**

I. INTRODUCTION

Municipal Corporation of Greater Mumbai (MCGM) has taken a lot of effort to reduce the waste going to the dumping ground from 8500MT per day in 2015 to 6900 MT per day in 2019. Modern technologies, newly designed dumpers, and various methods to generate energy from waste are used to achieve this task. Despite that, we can observe that all water bodies and drainage systems are polluted with garbage. This affects the health of the people and the scenic beauty of Mumbai. One of the reasons behind this situation is the inefficient management of household waste.

This paper describes how the Tragedy of Commons is applicable in household waste management. This paper also explains why reusing waste is necessary for sustainable development. A cost-benefit analysis of HW has also been done in this paper. A survey was conducted to understand and point out the difficulties faced by households in waste management, and to examine whether the MSW 2016 rules are well advertised and implemented.

II. THE TRAGEDY OF COMMONS AND HOUSEHOLD WASTE MANAGEMENT

The English Mathematician and Economist William Forster Lloyd, in 1833, in his lectures on "Checks to Population Growth" introduced the concept of overuse of commons by its commoner. It was later developed by the economist H. Scott Gordon and after that, by the ecologist Garret Hardin in his paper "Tragedy of Commons"[1]. The situation of the tragedy of commons is as follows. Consider a situation where a pasture is open to all. It is

[1] Hardin, Garrett. "The Tragedy of the Commons." *Science*, vol. 162, no. 3859, American Association for the Advancement of Science, 1968, pp. 1243–48, http://www.jstor.org/stable/1724745.

expected that each herdsman will try to keep as many cattle as possible on the common (pasture). After a point of time, the very practice will end in a tragedy because every rational herdsman will seek to maximize his gain by increasing the number of cattle, which in turn will start affecting the pasture. Each herdsman is thus locked into a system that compels him/her to increase his /her herd without limit in a world that is limited.[2]

This paper explores how the problem of waste management can be related to the 'Tragedy of Commons'. Each household considers their own share of the cost of waste they letting out into the common versus the cost they will incur if they will segregate the waste at the source. So, when all the households start shirking away from their responsibility of segregation and composting because of the extra effort one has to take, we are locked into a system that ends up in the collection of 6900 metric tons of waste per day in Mumbai. This is because every household has the freedom to choose what they want to do, and naturally, most people will only consider their best interest rather than thinking about the society as a whole. As Hardin said, "Population problem has no technical solution; it requires a fundamental extension in morality" [3], Solid waste management also has no sustainable technical solution. According to the researcher, the solution is to follow nature's 'Circularity Principle' and strictly implement the MSW 2016 rule, which has been discussed further.

III. THE MSW 2016, RULES

In 2016, the Ministry of Environment revised Solid Waste Management Rules, whereby it mandated segregation of waste at the source so that this waste could be turned into wealth through 'recovery, reuse and recycle'. The new rule makes waste management the responsibility of the waste generator so that it can be handled in an efficient, decentralized manner without overburdening the limited public resources and infrastructure. All manufacturers of disposable products such as tin, glass, plastics packaging etc. should put in place a system to collect back the packaging waste generated due to their production. Used sanitary waste like diapers, sanitary pads should be wrapped securely in pouches provided by manufacturers or brand owners of these products or in a suitable wrapping material and shall place the same in the bin meant for dry waste / non- bio-degradable waste. They also stipulated that within six months of the notification of the rules, local authorities must draw up a comprehensive waste management strategy according to their state policies. Thus, the Solid Waste Management policy of each Indian city is governed by the unique bye-laws framed by its urban local bodies.

The composition of HW is as follows: Organic Waste

- Wet waste (a)– fruit/vegetable peels, waste tea powder, coffee beans, landscape and pruning waste, other green waste, processed food, raw food materials, meat and bones, food-soiled paper, eggshells, leaf plates. (These can be easily converted to good organic compost by vermicomposting or by any other method)

(b) – Food leftovers, meat and bones, food-soiled paper (These can be used in biogas plants)

- Dry waste – Newspapers, magazines, brown paper, paper bags, paper packaging materials, ribbons, strings, leaflets, notebooks, wood, furniture. (Most of these are recyclable.)

Non-organic Recyclable waste (solid rubbish)

- Plastic – Plastic bags, containers, jars, bottles, covers, caps, milk pouches, food packets, soda bottles, wrappers.
- Metals– Utensils, batteries, pipes, nails, tools, aluminum foils, metal scraps, tetra packs, wires.
- Glass– Bottles, plates, cups, shards, mirrors, ceramics.

Hazardous waste

- Insect sprays
- syringes, diapers, sanitary napkins, cleaning chemicals, bleach containers, corrosives, flammable liquids, solvent-based paint, car batteries, e-waste, bio-medical waste.

As per the rules it is the mandatory for the housing societies to manage the waste. But how far have these rules been effective?

[2] Ibid

[3] Ibid

IV. Research Methodology

A. *Research Type and General goal*

- *The proposed research is applied, descriptive* and exploratory
- The proposed research is developed from qualitative point of view

B. *Target population and Sample Size*

- The population of the proposed research is all the households in Mumbai.
- A sample size = 153 households

C. *Data Collection Method*

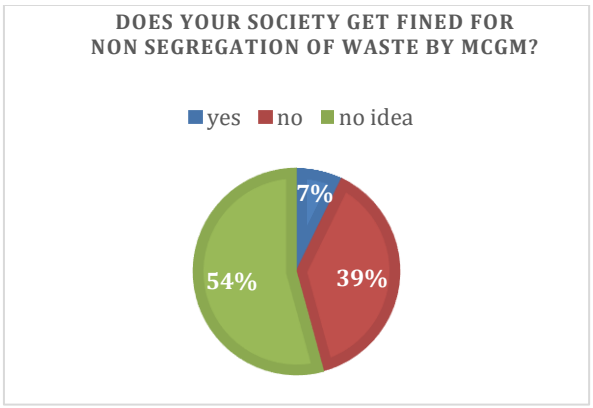
- The primary data was collected by sending out a questionnaire through google forms on social media platforms, specifically reaching out to all the Mumbaikars.
- The questionnaire was sent to a random 153 respondents for an unbiased result.

D. *Data Analysis Techniques*

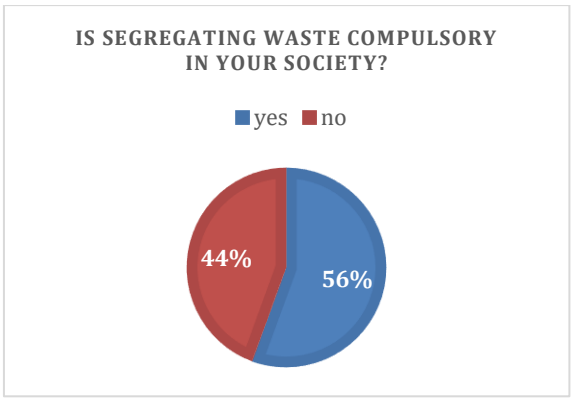
- The research hypothesis of the percentage of composting practices at the housing society level has been proved using the Z test.
- The data analysis of this research from the survey conducted has been mostly represented on a qualitative manner.

V. Research Analysis

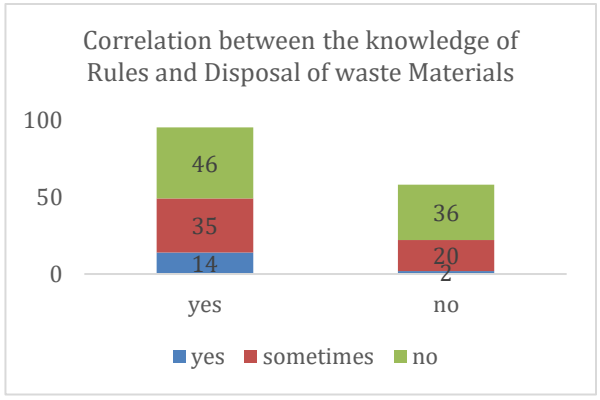
Fig(1)



Fig(2)



Fig(3)



Fig(4)

A *Inference*

1) The pie chart in fig (1), depicts that while 62% of the sample population are aware of Solid Waste Management Rules, 2016, the remaining 38% are unaware about it. This implies that there is still a considerable amount of the population that lack awareness of these rules and regulations.
2) Fig (2) reveals that the Rules are not strictly implemented in Mumbai.

3) The diagram in fig (3) proves that the claim of the municipality that 83% of segregation is done at the source is not entirely true.

4) The correlation coefficient calculated for the people who knows the MSW 2016 Rules and who dispose the package material in the collection bin is 0.184. Fig (4) reveals the same.

Testing of Composting practice in housing societies

Hypothesis:

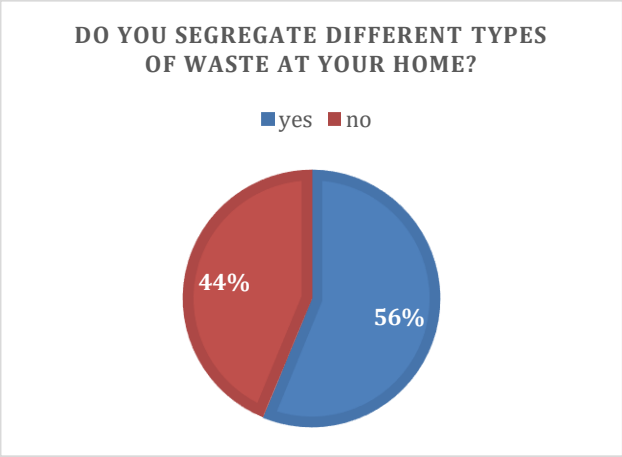
From the survey, out of 153 collected samples, 18 housing societies have composting practice p=18/153 and tested this against P=0.1.

H_0: The composting practice at the housing society level is less than 10% in Mumbai i.e. p<0.1

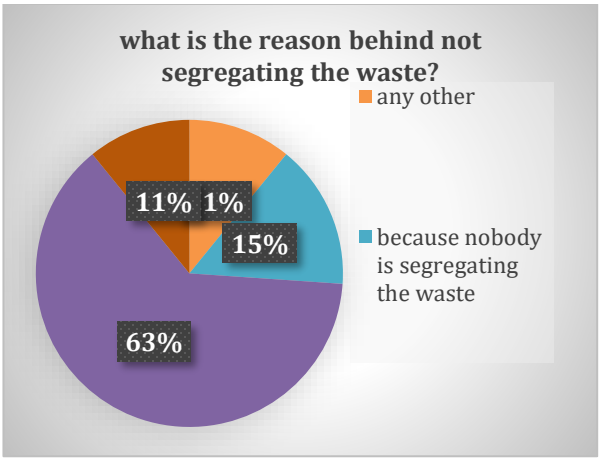
H_1: p≥ 0.1

z_t= 0.7276 <1.96

5) Thus, we see that composting practice at the housing society level is less than 10% is acceptable at a 5% significance level. This shows that composting is practiced by few housing societies in Mumbai.

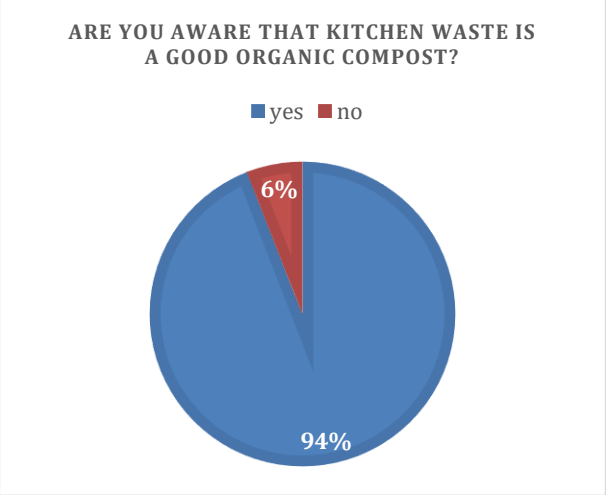


Fig(5)

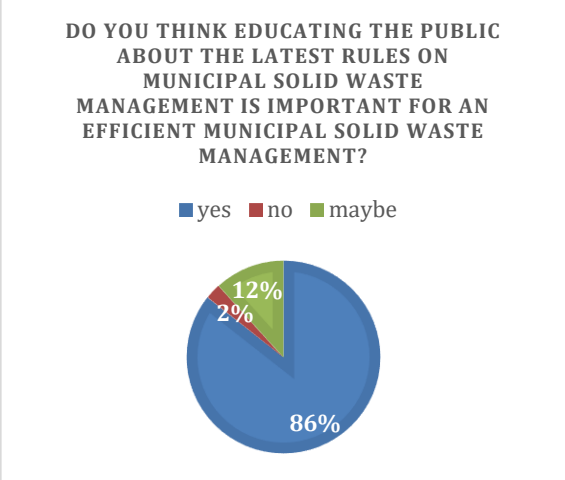


Fig(6)

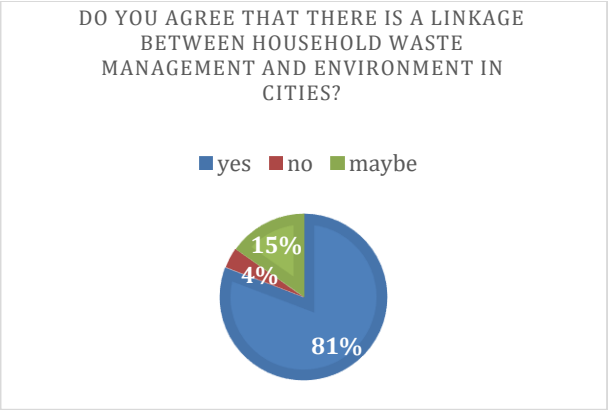
6) The above fig depicts that for 63% of the total population the main reason behind not segregating the waste is the use of one dustbin and dumping everything in one garbage bag and posing a massive challenge of waste sorting.



Fig(7)

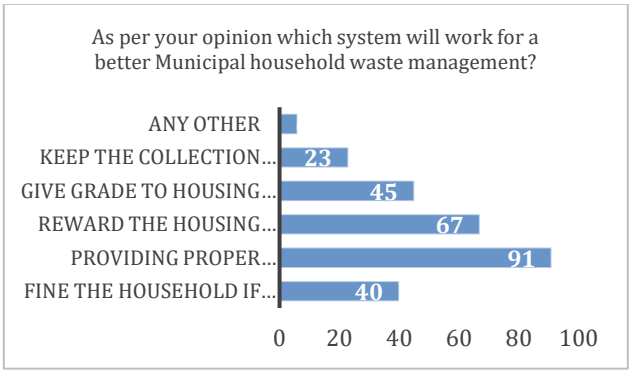


Fig(8)



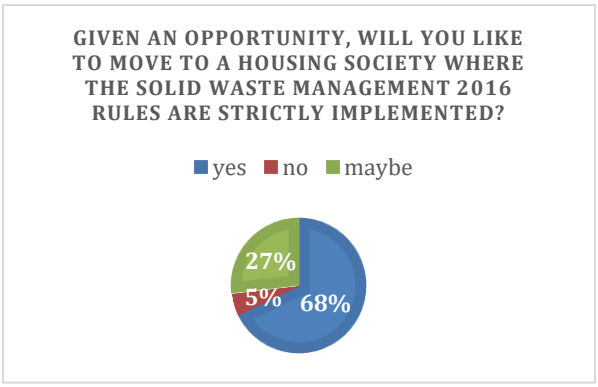
Fig(9)

7) The above diagrams show that the majority of the public agrees that kitchen waste is a good organic compost, educating the public about Solid Waste Management Rules is important and that there is a linkage between household waste management and the environment in cities.



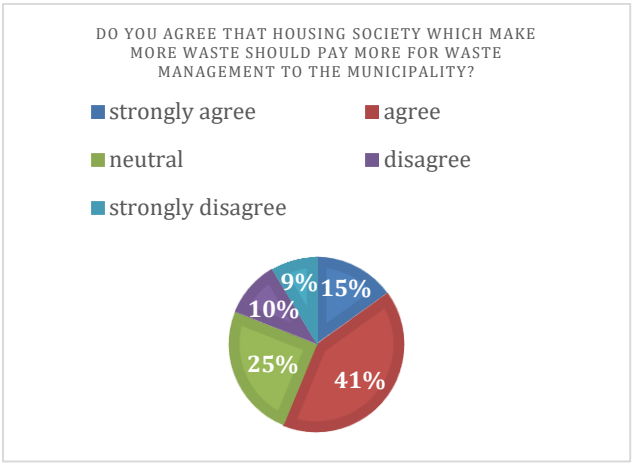
Fig(10)

8) Fig (10) points out that for better household waste management, we first need a better design of dustbins. Secondly, rewarding the housing societies in terms of tax reduction can also prove beneficial. Thirdly, grading the housing societies as per waste management efficiency and providing benefits accordingly can also help waste management at the household level. A dustbin with three boxes inside for segregating the 3 types of organic waste; compostable, non-biodegradable but recyclable, and other types of waste will help segregation. The garbage collector must also have the same type of collection bin. The first two types of waste are to be recycled at the housing society level by composting and giving the recyclable waste to rag pickers.



Fig(11)

9) It is very clear from fig (11) that people are ready move to a society where the SWM 2016 rules are strictly implemented.



Fig(12)

10) More than half the total population agree on polluter pays principle.

Table(1)

	yes	May be	no
Do you agree that there is a linkage between household waste management and environment in cities?	81%	15%	4%
Do you agree that your participation is important for a better Solid Waste Management in a housing society?	88%	11%	1%
Do you think educating the public about the latest rules on municipal solid waste management is important for an efficient Municipal Solid Waste Management?	86%	12%	2%
Given an opportunity, will you like to move to a housing society where the solid waste management 2016 rules are strictly implemented?	68%	27%	5%
Do you segregate different types of waste at your home?	56%	….	44%
Does, your society have compost pit or any other composting practice?	12%	33%	55%

11) The above table exposes that the public in Mumbai are aware of the importance HWM but they seldom recycle the waste. Which proves that "The Tragedy of the Commons" is applicable in HWM.

VI. COST/BENEFIT ANALYSIS OF SEGREGATION AND COMPOSTING OF HOUSEHOLD WASTE

Table(2)

Sr. No	Item	Data
1	Estimated expenditure for SWM in Mumbai[4]	Rs. 348.26 crores
2	Waste generated per day in Mumbai [5]	6900metric tones
3	Number of households in Mumbai[6]	674339
4	Estimated waste generated by households per day in the city	2 kg
5	Waste generated by households in Mumbai per day (674339*2)	1348 metric tones
6	Yearly expenditure for household SWM =348.26*1348/6900	Rs. 68 crores
7	Estimated Volume of waste generated by households per day	0.005cu. m
8	Space needed per year for household waste (674339*365*0.005)	1230668 cu. m
9	Organic waste generated by households yearly (0.6×2×365)	438kg

Cost/Benefit Analysis of segregation and composting of waste (at Municipality level)

Table(3)

Item	Cost in Crores	Item	Benefit in Crores
The cost to provide new dustbin to households one time investment @750	Rs. 50.58	Reduction in SWM expenditure (Table1(6)	Rs.68
Benefit	Rs. 29.73	Saving the cost of land used for dumping @ Rs. 100/cu. m	Rs.12.31
Total	Rs. 80.31		Rs.80.31

Cost/Benefit Analysis of segregation and composting of waste (housing Society considering a Housing society having 25 members)

Table(4)

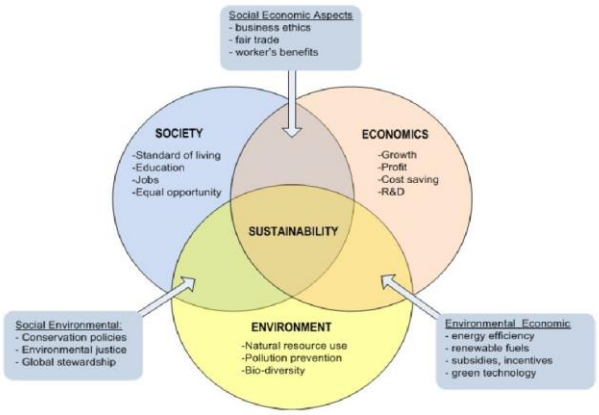
Item	Cost	Item	Benefit
Construction of compost pit (25000 distributed over 5 years)	**Rs.5000**	**The income from compost per year per household 438@2 (Table 1(9))**	**Rs. 21900**
Cost of newly designed collection bin(10000 distributed over 5 years)	**Rs. 2000**		
Excess Salary to Gardner 12*2000	**Rs.24000**		
		Excess cost	**9100**
Total	**31000**		**31000**

There is an excess cost of Rs. 9100 for the housing society. Therefore, the additional cost to the house hold will be Rs. 364. To facilitate segregation the proposal is to give a rebate of 5% in tax for the societies.

VII. HOW WILL THE RECYCLING OF HOUSEHOLD WASTE HELP IN THE SUSTAINABLE DEVELOPMENT OF MUMBAI?

Sustainable development involves environmental, economic and social aspects.

The three Pillars of sustainability[7]



Fig(12)

6 "MUNICIPAL CORPORATION OF GREATER MUMBAI SOLID WASTE MANAGEMENT." Maharashtra Pollution Control Board, Maharashtra Pollution Control Board, www.mpcb.gov.in/.

[5] Ibid

[6] "Demography." *Demography | Mumbai City | India*, Government of Maharashtra, mumbaicity.gov.in/about-district/demography/.

[7] Fedkin, Mark. "1.1 Sustainability Definitions." *EME 807: Technologies for Sustainability Systems*, Pennsylvania State University, www.e-education.psu.edu/eme807/node/575.

The following are the benefits of proper HW management.

Economic Benefits

From the above cost-benefit analysis, the economic benefit of MCGM is around Rs. 29.73 crores per year (Table 2) and each household have to shell out an amount of Rs. 364 for the additional cost for waste management. Which can be met by the tax rebate.

Social Benefits

Ragpickers can benefit greatly from the segregation of non-organic, recyclable waste.

Environmental Benefits

- Increases the life of dumping grounds
- Reduces environmental impact by reducing the transportation of waste.
- Nutrients of the waste get recycled.
- Farmers around Mumbai will benefit from the availability of organic compost which will be cheaper than chemical fertilizers, thus reducing the use of chemical fertilizers.
- The city public will benefit from organic food items.

The Ecosystem Services for a sustainable household waste management

Ecosystem services (ES) are the conditions and processes through which natural ecosystems, and the species that make them up sustain and fulfill human life. These are the processes by which the environment produces resources that we often take for granted such as clean water, timber, habitat for fisheries, pollination of native and agricultural plants, etc. Classifications of ES, given by the Millennium Ecosystem Assessment (MEA) are as follows:[8]

- Provisioning Services: Food, medicinal resources, crops raw materials, animal-based resources, energy, etc.
- Regulatory Services: Carbon sequestration, waste decomposition, purification of water and air, etc.
- Cultural Services: Spiritual, recreation and tourism, aesthetics, etc.
- Supporting Services: Nutrient cycle, soil formation pollination, and gene pool protection, etc.

The ES (Ecosystem Services) have the scope of being used for sustainable HW management. The vermicomposting and other natural bacterial composting methods are easy and need one-time investment for making compost pits, and services of the part-time employees for housing societies. The supporting services of ES will convert the waste into valuable compost and this compost in turn can be used as organic compost for the millions of farmers in nearby Mumbai. It facilitates nutrient flow and soil formation. What is required here is a strict implementation of policies which will encourage Research and Development .

CONCLUSION

Hardin, in his paper, points out that when it comes to the common, one receives two contradictory communications-

(1) Intended communication "If you don't do as we ask, we will openly condemn you for not acting like a responsible citizen."

(2) Unintended Communication

"If you do behave as we ask, we will secretly condemn you for a simpleton who can be shamed into standing aside while the rest of us are exploiting"[9].

In the case of recycling waste also, people are not following the rules because of the above unintended communication one receives. In a world where everyone is trying to maximize their own benefit and protect their own interest, people would seldom choose to do what is asked of them because there are people who continue to exploit resources and gain from them. Thus, according to the researcher, to save our commons, our rivers, forests, sea, air, etc., inculcating responsible behaviour in our children and public is a better option than investing in technology. In this matter, the role of teachers and parents is very important. One of the outcomes of school and college education must be the inculcation of this responsible behaviour in students.

[8] Field, B.C, and M.K Field. *Environmental Economics: an Introduction to Sustainable Development Review*. 1997.

[9] Hardin, Garrett. "The Tragedy of the Commons." *Science*, vol. 162, no. 3859, American Association for the Advancement of Science, 1968, pp. 1243–48, http://www.jstor.org/stable/1724745.

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