# Water Pollution arising from Laboratory facilities of Educational Institutions indulging in Hazardous Chemicals

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**Abstract**—Laboratories of Engineering and Science institutions are major producers of diverse hazardous waste-streams. As these are quite often acidic and laden with heavy metals, their direct disposal can lead to catastrophic environmental concerns. The situation hence warrants achieving a sustainable integral waste management system, but this is not achievable until the intensity of pollution is known. In this regard, the present research attempts to unravel the magnitude of water pollution that arises as an outcome of chemical experiments carried out at laboratories from a typical Engineering college. The Research Methodology sequentially envisaged primarily listing all experiments within the scope of study along with their detailed procedures, followed by compilation of reagent list. Then the preparation of each reagent was determined from 'Standard Methods'. Further, the strength of each chemical constituent for every experiment was computed to derive 'net strength', based on 'frequency' of conduction of individual experiments. Finally the obtained results were statistically analyzed for comparison, along with 'Water Quality Standards' and 'Effluent Standards'. The study concludes with a quantitative, qualitative and composite outlook to the problem.

**Index Terms**—experiments, laboratory, metals, toxic, waste.

## 1 Introduction

One of the fundamental responsibilities in 'Water and Wastewater Management' is to ensure the reliability and validity of analytical laboratory data gathered [1]. Very often Engineering and Science laboratories engaged within Departments of Civil, Chemical, Environmental, Pharmacy and Biotechnology (Figure 1) are engaged in a range of experiments involving hazardous chemicals [2].

Fig. 1: A typical outlook of Laboratory engaging in Chemical analysis.

Hazardous chemicals are defined as "materials which are of no further research, academic or commercial use, and which cannot be recycled, reclaimed or rendered non-hazardous" [3].


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In this context, laboratories from the aforementioned departments generates a wide array of waste, comprising of acidic hazardous waste and mixture of wastes, in both solid and liquid form; and may include polycyclic aromatic hydrocarbons, flammable liquids, oxidizers, toxic substances and corrosives etc. These can originate as either concentrated and dilute forms; and take the form of stock/standard solutions, reacted and un-reacted solutions, test solutions, spillages, expired discards etc.

Apart from the complexity in safely disposing these diversified wastes, also coordinating hazardous waste management at a college or university level is further nerve cracking since most colleges and universities are decentralized, and within whom wherein most academic and administrative departments function independent of each other.

To make matters worse, at most research laboratories the 'type of operations' and 'waste generation' fluctuates frequently once the focus of the research changes [4]. Also to compound issues at various stages of experimentation; owing to the sheer negligence and ignorance; the faculty, students, researchers and laboratory instructors quite often tend to discard the hazardous substances into the sink without any second thoughts.

## 2 Literature Review

While published data on laboratory waste management have often divulged generic measures on generation such as microscaling [5], green chemistry, inventory control etc. [6], only few have converged on waste assessment and reduction.

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In 1991 Ohio EPA had conducted a study to identify the amount, types and sources of hazardous waste generated by laboratory facilities from the Lake Erie Basin of Ohio [7]. Nevertheless, the literature survey has clearly indicated that no credible research has been conducted in the present context of estimating the net quantity/strength of individual chemical used in Educational and Research and Development laboratories. This comes as a major concern since regulatory changes enacted through the Hazardous and Solid Waste Amendments of 1984 has put new restrictions on the hazardous waste disposal for the small quantity generators, i.e., those producing between 100 kg and 1000 kg per calendar month. This includes many small laboratories that are now subject to specific 'Resource Conservation and Recovery Act' (RCRA) regulations [8].

## 3 Scope Of Study & Methodology

Establishing the contents of laboratory waste stream is imperative to designing of pollution waste management system. In the scope of present objective, the current study attempts to unravel the intensity of water pollution that arises as an outcome of chemical experiments, carried out at Engineering Chemistry and Environmental Engineering laboratory facilities of educational institutions, within the framework of syllabus per semester. While the former laboratory is conducted every semester (twice a year), the latter laboratory is conducted every alternate semester as an integral academic requirement of the Department of Civil Engineering, and hence its conduction is restricted to a single semester each year.

The Research Methodology was achieved in the following sequence. Primarily, the list of all experiments within the scope of study along with their detailed procedures and reagents list were compiled. This was followed by the determination of the preparation of each reagent from the 'Standard Methods' [9]. Further, the strength of each chemical constituent for every experiment was computed to derive 'net strength', based on 'frequency' of experiments and number of trials/analysis to eventually yield Quantitative, Qualitative, and Composite assessment. While Quantitative assessment refers to magnitude of potential generation/usage or the contamination of heavy metal/pollutant for the individual experiments, Qualitative assessment refers to strength of the same. Lastly Composite assessment refers to individual strength of heavy metal or pollutant in waste stream when all experiments are considered to be as single daily entity in terms of water disposed into the sink, and hence this parameter hints at probable highest dilution capacity.

Finally the obtained results were statistically analyzed for the deviations, by comparing with Bureau of India (B.I.S.) derived 'Water Quality Standards' and 'Effluent Standards' [10]; in lieu of possible contamination with water supply lines or entry into public sewers potentially leading to a water-body or sewage treatment plant or land.

## 4 Results And Discussion

As can be observed from Table 1, the results tabulated for Environmental Engineering laboratory apply for experiments of a single semester only, and ignore R&D contributions from students and staff alike. The Quantitative Assessment apart from clearly presenting the vast volume of water spent in individual experiments/reagent preparation also highlights the excessive usage of strong acids as precursors/reactants in experiments; apart from also serving as cleaning agent. From the Qualitative assessment, it can be also highlighted that all heavy metals/pollutants present/discharged into the sewers are occurring at magnified levels. For instance, though Manganese is used sparsely in the laboratory experiments, yet its brief application tends to exist in an extremely concentrated state. Hence, though the overall individual quantity of heavy metal/pollutant generation is lesser in Environmental Engineering Laboratory, its diversity is multifold, thus making it challenging to suggest recovery or disposal measures.

TABLE 1
Computed Strengths of Environmental Engineering laboratory for individual chemical discards.

| Hazardous substance | Quantitative Assessment | Qualitative Assessment [mg/l] | Composite Assessment [mg/l] |
|---|---|---|---|
| **Potassium** | 151853.18 mg/15L | 10123.55 | 2052.07 |
| **Chloride** | 263316.68 mg/17L | 15489.22 | 3558.33 |
| **Iron** | 7282.3 mg/4l | 1820.58 | 98.41 |
| **Sulphuric Acid** | 3.80 L | -na- | -na- |
| **Calcium** | 10490 mg/3L | 3496.66 | 141.76 |
| **Hydrochloric Acid** | 0.50 L | -na- | -na- |
| **Ammonia** | 80211.40 mg/4L | 20052.85 | 1083.93 |
| **Magnesium** | 27430 mg/4L | 6857.5 | 370.68 |
| **Manganese** | 118250 mg/L | 118250 | 1597.97 |
| **Silver** | 11475 mg/L | 3825.00 | 155.07 |
| **Nitrate** | 2100.2 mg/3L | 700.00 | 28.38 |
| **Aluminium** | 400.00 mg/L | 400.00 | 5.41 |
| **Arsenic** | 2880.00 mg/L | 2880.00 | 38.92 |
| **Chromium** | 39358 mg/2L | 19679.00 | 531.86 |
| **Sulphate** | 427352.90 mg/15 L | 28490.19 | 5775.03 |
| **Barium** | 137330 mg/L | 137330.00 | 1855.81 |
| **Mercury** | 200590 mg/L | 200590.00 | 2710.68 |
| **Fluoride** | 100.50 mg/L | 100.50 | 1.36 |
| **Acetic Acid** | 3.20 L | -na- | -na- |

-na- Not Applicable

TABLE 2

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Computed Strengths of Engineering Chemistry laboratory for individual chemical discards.

| Hazardous substance | Quantitative Assessment | Qualitative Assessment [mg/l] | Composite Assessment [mg/l] |
|---|---|---|---|
| **Potassium** | 516223 mg/7500L | 68.83 | 11.4.72 |
| **Chloride** | 779221 mg/7500L | 103.90 | 17.32 |
| **Iron** | 3114200 mg/7500L | 415.23 | 69.20 |
| **Sulphuric Acid** | 20.00 L | -na- | -na- |
| **Mercury** | 200592 mg/7500L | 26.75 | 4.46 |
| **Hydrochloric Acid** | 20.00 L | -na- | -na- |
| **Chromium** | 530278 mg/7500L | 70.70 | 11.78 |
| **Nitric Acid** | 5.00 L | -na- | -na- |
| **Copper** | 516223 mg/7500L | 68.83 | 11.47 |

-na- 'Not Applicable'

TABLE 3
Drinking Water Quality and Effluent Standards [10]

| Hazardous substance | Water Quality Standards [mg/l] | Effluent Standards [mg/l] |
|---|---|---|
| **Potassium** | -- | -- |
| **Chloride** | < 250.0 | 1000 (public sewers) |
| **Iron** | < 0.1 | 3.0* |
| **Sulphuric Acid** | -- | -- |
| **Calcium** | < 75.0 | -- |
| **Hydrochloric Acid** | -- | -- |
| **Ammonia** | < 0.5 | -- |
| **Magnesium** | < 30.0 | -- |
| **Manganese** | < 0.1 | 2.0* |
| **Silver** | < 0.02 | 5.0 (public sewers) |
| **Nitrate** | < 45.0 | 10.0 (water body) |
| **Aluminium** | < 0.03 | 5.0* |
| **Arsenic** | < 0.05 | 0.2* |
| **Chromium (VI)** | < 0.05 | 0.1 (water body)<br>2.0 (public sewers) |
| **Sulphate** | < 150.0 | 1000 (public sewers) |
| **Barium** | < 1.0 | 10.0 (public sewers) |
| **Mercury** | < 0.001 | 0.01* |
| **Fluoride** | < 1.0 | 2.0 (water body)<br>15.0 (public sewers) |
| **Nitric Acid** | < 80.0 μg/L | -- |
| **Copper** | < 0.05 | 3.0* |

*Effluent Standards are same for both 'inland surface water' and 'public sewers'.

-- 'Data not available'

Table 2 showcases results for the Engineering Chemistry laboratory. The results basically comprise values of experiments only for 1 semester, though they are repeated/conducted twice a year, and have also ignored staff R&D contribution. As observed, the Quantitative assessment depicts a huge volume of 7500L for each experiment/reagent preparation. This is hence vindictive of the total quantity of water spent throughout semester for a single laboratory experiment encompassing about 500 students. When compared with Table 1, Engineering Chemistry laboratory presents a picture more of generic features. However, from Qualitative assessment point of view, it needs to be registered that though the waste volume arising from the Engineering Chemistry laboratory is quite vast, its strength is yet quite significantly high and hence designing its treatment process is still a colossal task.

From Tables 1 & 2, when results of both Quantitative and Qualitative assessment is compared with 'Standards' tabulated in Table 3, as recommended by B.I.S. [10]; the deviations visibly hint at the probable ecological and environmental threat not only from the college under purview, but also when contribution of similar laboratories from all other existing colleges and/or R&D facilities is considered.

Finally, even the results for Composite assessment indicate that all the major chemicals made use of in both laboratories are way above the 'Standards' recommended by B.I.S. In this context, a noteworthy point to be clarified/debated is the general opinion projected by experts that the waste generated from the educational facilities need not be pondered about since they are quite negligible as they are disposed of with huge volumes of water, i.e. dilution as a parameter shall take care of the pollutant concentration. However, as can be perceived from the outcome of Composite assessment extracted from Tables 1 & 2; despite the highest dilution factor considered the resultant values depict significantly higher concentrations/strength than the stipulated standards.

To recapitulate, one can observe that though the waste generated in laboratories are more toxic than domestic sewage, yet they are lesser in toxicity than specific industrial effluents. Also, as the waste volume is not large when compared to typical municipal/industrial outfalls and since the diversity of wastes is quite considerable; they still pose unique waste management problems. The present situation hence demands that special consideration be initiated and mandated, while designing a pollution prevention program for any research/educational institution. As neither the water quality standards nor effluent standards apply to the laboratory management scheme, the need of the hour suggests that new regulations be postulated and enforced. Also the reckless and ignorant attitude of handlers in discarding toxicants can be resolved by constant internal/Government auditing, in-situ centralized treatment, sustainable experiments and finally by better house-keeping practices.

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## 5 Limitations and Future Scope of Study

Due to practical constraints, the present study has exempted the individual role of stronger contributor's namely fully fledged developed Departments of Environmental and Chemical Engineering. These departments deal with more diverse toxic components throughout the academic calendar, with minimum four laboratories running parallel each semester. The study also overlooked other smaller laboratory operations within the study area which could have otherwise projected a compete scenario of overall pollution from the institution as a whole. The study also excluded high-school science laboratories. Though all these sources are conditionally exempt from the hazardous waste regulations, they are also sometimes unaware of the regulations and environmental consequences. This concern is not represented in this report. The results have been presented only keeping university syllabi in mind, and ignoring the Research and Development experiments/analysis, the role of which could further intensify, diversify and tangle the issue.

From the results, it has become most evident that laboratory waste management needs to be readdressed with more focused and logical insight, also the matter is more grim since as can be observed from Table 3, quite a few chemicals are yet to be affixed with maximum permissible and threshold limits in drinking water and municipal/industrial effluents. Hopefully this article drives future research to come up with solutions to address issues on developing laboratory specific disposal standards and regulations. The future studies apart from probing the limitations addressed in previous paragraph, can also undertake the analytical aspects to understand the synergistic reactions occurring in the sinks/sewers and also to conceptualize/design centralized requisite in-situ treatment.

## 6 Conclusion

This case study highlighted new facet of hazardous waste generation, in the Divisions of Engineering Chemistry and Environmental Engineering laboratory. From the results it was found that, certain chemicals though were handled in diluted state, its enormous volume discarded to sinks was a matter of grave concern, and while those discharged in concentrated state could nevertheless have direct and synergistic effects on the environment. As under current regulations, all generators including small scale laboratories are also responsible for safe cradle-to-grave management for any hazardous waste that they generate, therefore they must recognize the need to reassess existing chemical waste management within their organizations.

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