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The Effect of Flow-Distance of Industrial Wastewaters on Correlation between Chemical and Biochemical Oxygen Demands

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Authors' contributions

This work was carried out in collaboration between all authors. Authors OMM and AOL designed the study, performed the statistical analysis, wrote the protocol and the first draft of the manuscript. Authors BMA and AE managed the analyses of the study and the literature review. All authors read and approved the final manuscript.

Original Research Article

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ABSTRACT

Aims: The aim of this study was to investigate the influence of flow-distance on the empirical correlation between biochemical oxygen demand (BOD_5) and chemical oxygen demand (COD) of wastewaters from a cluster of industries.
Study Design: Wastewater samples were collected at point-sources and at 25, 50, 75 and 100m distances from the point-sources.
Place and Duration of Study: Nasco Household Products Ltd. Laboratory, Jos, Nigeria. Sampling was done twice a week for a full seasonal cycle at peak production period (morning and evening).
Methodology: The samples pH were adjusted to 7 using 0.5M acid for basic samples and 1M alkali for acidic samples, de-chlorinated using 0.0125M $Na_2S_2O_3$ and seeded when necessary and then diluted with de-ionized water. The dissolved oxygen (DO) content of the diluted sample was determined before and after incubation for 5 days by azide modified Winkler's method. The difference, taking into account the dilution, gave the BOD_5 of the sample. For COD the sample to be measured was oxidized under reflux by 0.125M potassium dichromate and 2mg of sulphamic acid with silver sulphate as a

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catalyst and a suppressor of chloride interferences. Organic matter reduced part of the dichromate and the remainder was determined by titration with iron (II) ammonium sulphate using ferrion as indicator.
Results: The empirical correlation between COD and BOD_5 was generally maintained despite the distance of flow of the wastewater from point-source and contributions of washings from farmlands and other human activities. COD and BOD_5 of the wastewaters from different sources highly correlated with correlation coefficients ranging 0.9396-0.9985.
Conclusion: The correlation between COD and BOD_5 for wastewaters was not affected by flow distance. The correlation equations for the industries may therefore be used to deduce rapid effluent quality from chemical oxygen demand (COD) of sample from any point along the effluent flow.

Keywords: Wastewaters; flow-distance; BOD; COD; correlation; pollution.

1. INTRODUCTION

The environmental concern about water is as a result of the fact that the accessible portion of water for human use is greatly affected by various human activities such as technologies for processing raw materials into utilizable finished products, mining activities, oil explorations for energy supply, production of organic and inorganic fertilizers for agricultural purposes, synthesis of pesticides to fight pests, herbicides to kill weeds, production of textiles, detergents, soaps, chemicals and pharmaceuticals [1,2,3]. Generation of wastewaters in industrial processes is sometimes unavoidable and in most cases a process to reduce the organic load and other contaminants must be employed [4]. Although sewage and industrial waste have desecrated most of the waterways near large centers of population, sewage water may be purified enough to be used for drinking purposes [5]. As the most abundant liquid on earth, water runs steadily along vast network of rivers while transporting wastes alongside over long distances [6].

Interestingly, it seems as if nature can handle its own wastes effectively through the processes of decomposition and movement of materials in the ecosystem thereby maintaining a balance in the ecosystem [6]. Nature is also the recipient of human wastes many of which are not natural substances that nature can cope with. This forms the basis of environmental problems. Wastes from artificial systems have both physical and chemical properties. Their interaction with natural and artificial ecosystems on the earth surface defines the problem set by the waste in both magnitude and nature. The effects of wastes are very important and can be assessed through careful experimentation in relation to many organisms in the living world [6]. The effects can either be direct or derived through transformation, interaction and flow and accumulation but the most important point is that different materials have different effects on different targets. These targets are the different species of living organisms that waste can come in contact with.

The components of wastes can be classified into three categories: chemical, physical and biological contaminants. One major concern about chemical contaminants is that they pose a problem of depletion of dissolved oxygen (DO) as well as toxicity. Physical contaminants bring about issues of color, turbidity and radioactivity while biological contaminants are responsible for disease transmissions such as cholera, typhoid, etc. [7].

Industrial wastes may vary from one factory to the other depending on the nature of the operations. Despite the various differences in the nature of the industrial wastes, there are basic tests that can be used for their characterization [8]. The characteristics of wastewaters are very significant because they provide an indication of the treatment works required.

Oxygen depletion has been considered as one of the potential factors for cases of mass mortality, which is often associated with certain imbalance in the environmental parameters. Metcalf and Eddy [9] reported that the most widely used parameter for organic pollution measurement applied to both wastewater and surface water is the 5-day biochemical oxygen demand (BOD_5). The biochemical oxygen demand (BOD) is the amount (mg/L or ppm) of oxygen that bacteria take from water when they oxidize (or stabilize) organic matter. The test is performed at a defined temperature (20ºC) and for a standard period (5-days), hence BOD_5.

Environmental monitoring agencies usually request industries to submit their BOD_5 results of their wastewaters periodically. Also, optimal process control practice demands for these results, promptly, for effective management. However, due to long incubation periods and low reproducibility, most industries find it difficult to meet such deadlines. Even when they do, the results provide historical data and fail to facilitate rapid water quality assessment or optimal process control. Chemical oxygen demand (COD), a measure of the oxygen equivalent of the organic matter content of a sample that is susceptible to oxidation by a strong oxidant, is simple and can be reliably carried out in the laboratory. The dichromate reflux method has been preferred over procedures using other oxidants because of the superior oxidizing ability with wide variety of samples, and ease of manipulation [10].

Comparison of BOD with COD assesses whether the compound is readily biodegradable. For BOD_5, COD: BOD ratio greater than 100 is an indication that the compound is relatively non-biodegradable and a ratio of less than 10 means it is relatively degradable [11]. Low BOD_5 may also mean that the test microbes require longer test period to degrade the compound.

Attiogbe et al. [11] reported a highly positive degree of common variation ($y = mx + c$) between COD and BOD_5 for the effluents from Ghana Brewery Limited (GBL), Guinness Ghana Limited (GGL) and Coca-Cola Bottling Company of Ghana. Ajiga [12] reported a linear correlation of the type $y = mx + c$ between BOD_5 and COD for the wastewaters of Nasco Household Products Ltd., Nasco Foods Ltd., Nigerian Bottling Company (Coca-Cola) and Jos International Breweries Limited.

The present work, therefore, aims at determining the COD and BOD_5 of wastewaters from the cluster of industries at various distances from point-source in an attempt to determine the effect of flow-distance on the empirical relation between COD and BOD_5.

2. MATERIALS AND METHODS

2.1 Study Area

Jos is the capital of Plateau State and it is situated in North Central Nigeria. The area under investigation is between Anglo-Jos and Barakin Larawi in the Jos-South industrial area of the state. Situated in this area is Nasco Household Products Ltd. (NHPL; a chemical industry), Nasco Foods Ltd. (NF), Nigeria Bottling Company (NBC; Coca-Cola) and Jos International

Breweries (JIB), each having a furrow of wastewater that eventually combines into one wastewater body and empties into a nearby stream. Various farming activities also take place within the study area.

2.2 Sampling

Wastewater samples from each of the industries were collected at point–sources and at 25m, 50m, 75m and 100m distances from the point- sources (Fig. 1). Sampling was done twice a week for a full seasonal cycle at peak production period (morning and evening). When not analyzed immediately, the samples were kept in the refrigerator at 4^0C in pre-rinsed plastic containers with airtight plastic covers for preservation. Analyses were, however, carried out within 24 hours at the Nasco Household Products Ltd. Laboratory, Jos.

Fig. 1. Map of the study area showing the location of industries and sampling points

2.3 Biochemical Oxygen Demand (BOD_5): Dilution Method

The samples were treated by adjusting their pH to 7 using 0.5M acid for basic samples or 1M alkali for acidic samples, de-chlorinated using 0.0125M $Na_2S_2O_3$ and seeded when necessary and then diluted with de-ionized water. The dissolved oxygen (DO) content of the diluted sample was determined before and after incubation for 5 days using the azide modified Winkler's method. The difference, taking into account the dilution, gave the BOD_5 of the sample [13,14].

2.4 Chemical Oxygen Demand (COD)

The sample to be measured was oxidized under reflux using 0.125M potassium dichromate and 2mg of sulphamic acid with silver sulphate as a catalyst and a suppressor of chloride interferences. Organic matter reduced part of the dichromate and the remainder was determined by titration with iron (II) ammonium sulphate using ferrion as indicator [13,14].

3. RESULTS AND DISCUSSION

The average COD and BOD_5 results for the respective industries are presented in Tables 1, 2, 3 and 4. The BOD ranged from (5 – 42mg/L). The values in some of the locations were in excess of the maximum allowable limit of < 20 mg/L by the international and regional standards [15,16].

Table 1. Mean Chemical Oxygen Demand (COD) and Biochemical Oxygen Demand (BOD5) values for Nasco Household Products Ltd. (NHPL) wastewater

Parameter	Flow-Distance (m)				
	0	**25**	**50**	**75**	**100**
COD (mg/L)	1670	1723	1675	1539	1360
BOD_5 (mg/L)	26	25	23	18	12
COD/BOD_5	64	69	73	86	113

Table 2. Mean Chemical Oxygen Demand (COD) and Biochemical Oxygen Demand (BOD5) values for Jos International Breweries (JIB) wastewater

Parameter	Flow-Distance (m)				
	0	**25**	**50**	**75**	**100**
COD (mg/L)	8309	9568	10668	10751	10865
BOD_5 (mg/L)	14	16	17	29	42
COD/BOD_5	593	598	628	371	259

Table 3. Mean Chemical Oxygen Demand (COD) and Biochemical Oxygen Demand (BOD5) values for Nigeria Bottling Company (NBC (Coca-Cola)) wastewater

Parameter	Flow-Distance (m)				
	0	**25**	**50**	**75**	**100**
COD (mg/L)	763	1081	1516	2324	3296
BOD_5 (mg/L)	5	8	11	17	23
COD/BOD_5	153	135	138	137	143

Table 4. Mean Chemical Oxygen Demand (COD) and Biochemical Oxygen Demand (BOD5) values for Nasco Foods Ltd. (NF) wastewater

Parameter	Flow-Distance (m)				
	0	**25**	**50**	**75**	**100**
COD **(**mg/L**)**	727	1019	1300	1481	1559
BOD_5 **(**mg/L**)**	6	8	9	9	10
COD/BOD_5	121	127	144	165	163

From the results, the COD and BOD_5 values generally decrease with increase in flow-distance from the source-point in situations where the wastewater experienced minimal contributions from other human activities along the flow-path as the case with NHPL furrow.

The general trend from NBC and JIB furrows to where the respective effluents combined into one wastewater body is an increase in COD and BOD_5 values along the flow-path. This could be attributed to the level of human activities resulting in further pollution as the effluents flow downstream. Washing from farmlands lining the furrow is a major contributor of fertilizers, manures, human wastes, etc. into the furrow; resulting in more pollution and higher COD and BOD_5 values as the wastewater flows downstream. Presence of ammonia is reported to significantly increase measured BOD_5 as a result of microbial oxidation of ammonia to NO_3; ultimately [11]. The decrease in COD and BOD for NHPL wastewater may be due to lack of farming activities around the location. Farmlands were a bit distant from this furrow at the time of this study.

The average COD values ranged from (727 – 10,880mg/L). The observed comparatively very high COD values as compared to BOD_5 indicates presence of large amounts of organic compounds which are oxidizeable by $K_2Cr_2O_7$ but not biochemically oxidizeable [17]. This could also be accounted for by the reported high values of nitrites and Fe^{2+} in these wastewaters which accounts for non-detection of inorganic COD by the BOD_5 test [12]. The high values may also be associated with material loss from the industries.

The correlations between COD and the corresponding BOD values along the flow-paths of the wastewaters of these industries are presented in Figs. 2 – 5.

The plots of COD against BOD_5 show that the empirical correlation between COD and BOD_5 values is generally maintained despite the distance of flow of the wastewater from point-source and contributions of washings from farmlands and other human activities.

The fitted equations were: $y = 24.605x + 1086.9$, $R^2 = 0.9396$ (NHPL); $y = 63.429x + 8535.1$, $R^2 = 0.4544$ (JIB); $y = 142.59x - 23.681$, $R^2 = 0.9985$ (NBC) and $y = 258.38x - 911.41$, $R^2 = 0.9966$ (NF). The correlation equations could be used to estimate the BOD_5.

However, the COD and BOD_5 correlation was low for JIB; though the first three values showed a strong correlation ($R^2 = 0.9992$). The negative intercept (negative COD value) presented by the correlation equations of the wastewaters from NBC and NF could be attributed to the presence of metallic toxicants in appreciable quantities. These toxicants are reported to inactivate or kill the microorganisms (depending on concentration of the toxicant) that are supposed to feed on the waste, which results in a small oxygen drop and a very low BOD_5 value. Ajiga [12] reported high concentrations (3.1±0.02mg/L and 2.01±0.02mg/L) of Zn^{2+} and Cu^{2+} respectively for the NBC wastewater samples from point-source. Klein [17] and Ademoroti [18,19] reported that for every 1mg Cu^{2+} per liter wastewater, a BOD_5

suppression of 33% was recorded, while every 1mg Zn^{2+} per liter wastewater caused 17% BOD_5 suppression. Biologically treated effluents from pulp and paper have been reported to still contain significant amounts of colored compounds, microorganisms, recalcitrant organics and a minor amount of biodegradable organics, as well as suspended solids [20]. Reports on current treatment processes for petroleum refining effluents recommends Photocatalytic degradation as an attractive technique [21].

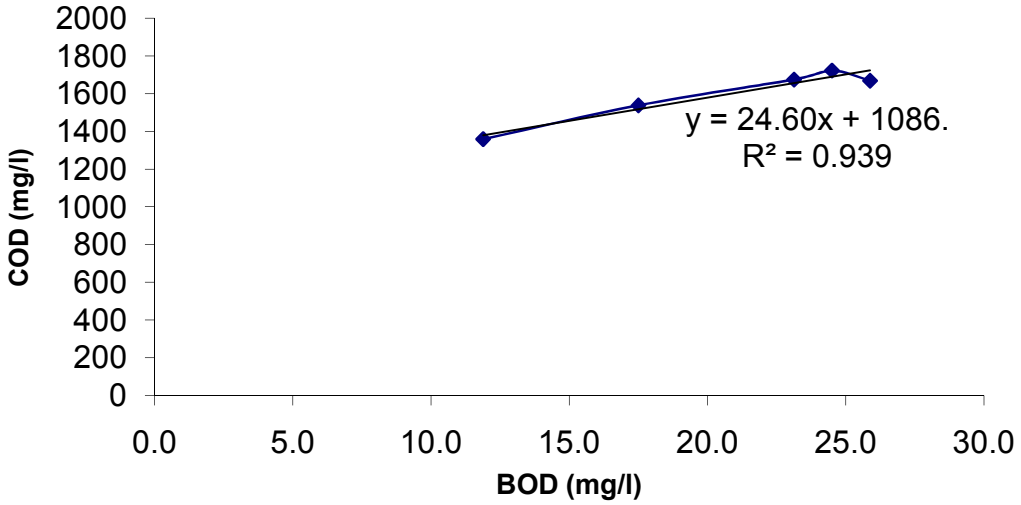

Fig. 2. COD-BOD_5 curve for Nasco Household Products Ltd. (NHPL) wastewater

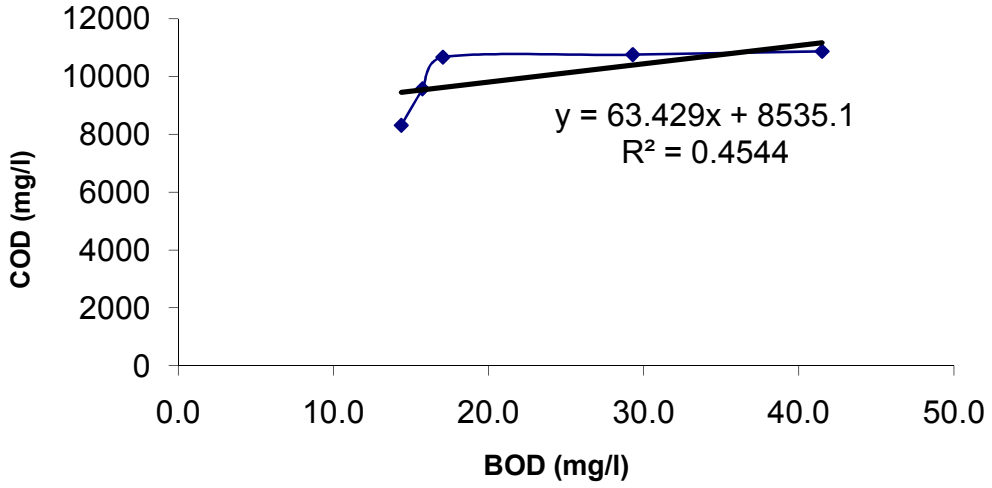

Fig. 3. COD-BOD_5 curve for Jos International Breweries (JIB) wastewater

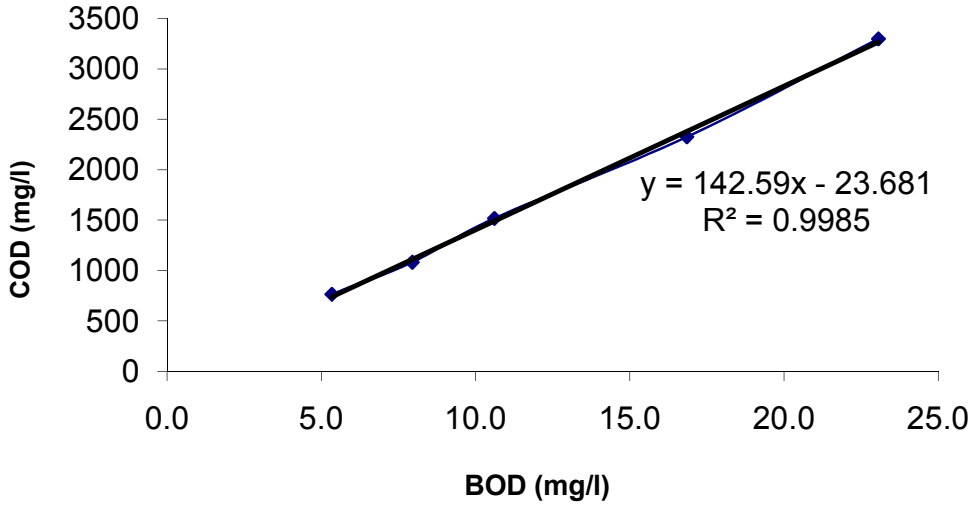

Fig. 4. COD-BOD_5 curve for Nigeria Bottling Company (NBC (Coca-Cola)) wastewater

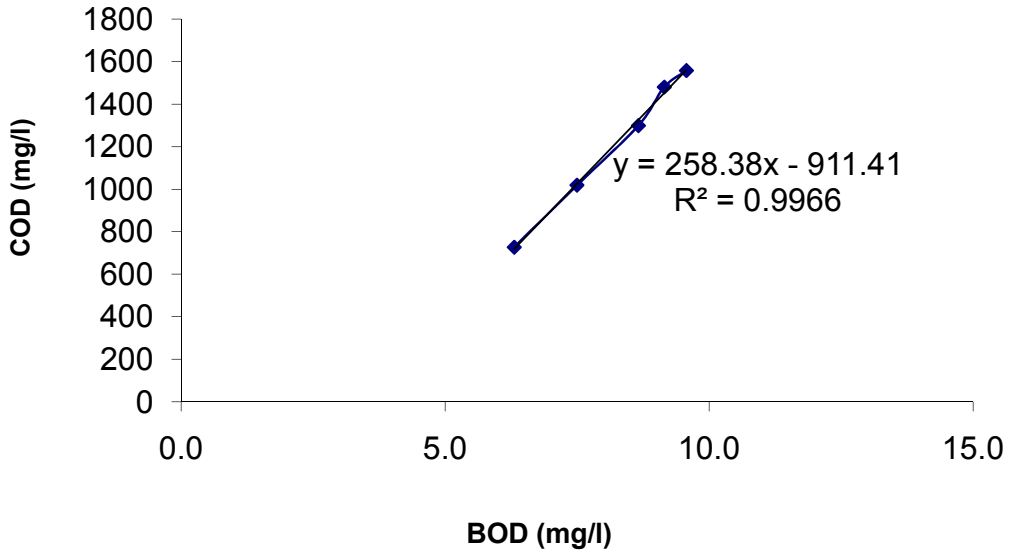

Fig. 5. COD-BOD_5 curve for Nasco Foods Ltd. (NF) wastewater

4. CONCLUSION

The correlation between COD and BOD_5 of the wastewaters was not affected by distance of flow. COD and BOD_5 of the wastewaters from NHPL, NBC and NF were highly correlated with correlation coefficients of 0.9396, 0.9985 and 0.9966 respectively; despite the flow distance from point-source. The fitted correlation equations for the industries may be used to

deduce rapid effluent quality from chemical oxygen demand (COD) of sample that may be taken from anywhere along the effluent flow channels.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Clark JW, Viessman M Jr. Water supply and pollution control, 3rd ed. Plenium Press; 1977.
2. Mohamed SAS, Naik M, Sanaulla PF, Zulfiqar AMN. Studies on contaminant transport at an industrial waste dumpsite of Bangalore, India. Ambi-Aqua. 2008;3(3):55-66.
3. Akpor OB, Muchie M. Remediation of heavy metals in drinking water and wastewater treatment systems: Processes and applications. Int J Phy Sci. 2010;5(12):1807-1817.
4. Nora San Sebastián Mart´ınez, Josep F´ıguls Fernández, Xavier Font Segura, Antoni Sánchez Ferrer. Pre-oxidation of an extremely polluted industrial wastewater by the Fenton's reagent. J Hazard Mater. 2003;101:315–322.
5. Andrew WA. Environmental Pollution, Plenium Press, New York; 1972.
6. Bradshaw AD, Wood RS, Warner F. The Treatment and Handling of Wastes. Chapman and Hall for the Royal Society; 1992.
7. Ramalho RS. Introduction to Wastewater Treatment Processes; 1977.
8. Kalmoff WJ, Muller DEB, Wagte T. Disposal of sewage and other water-borne wastes. Butterworth & Co. Publishers Ltd; 1971.
9. Metcalf and Eddy I. Wastewater Engineering: Treatment, Disposal and Reuse, 3rd ed. Tata McGraw-Hill Publishing Company Ltd; New Delhi; 1995.
10. Boyles W. The science of chemical oxygen demand. Technical Information Series, Booklet No.9, Hach Company, USA; 1997.
11. Attiogbe FK, Glove-Amengor M, Nyadziehe KT. Correlating Biochemical and Chemical Oxygend Demand of Effluents: A Case Study of Selected Industries in Kumasi, Ghana. West Afr J Appl Ecol. 2007;2:110-118.
12. Ajiga MB. The relationship between biological oxygen demand and chemical oxygen demand in industrial wastewaters and their resultant effects on the environment. Unpublished M.Sc. Thesis in the Department of Chemistry. University of Jos; 2008.
13. Ademoroti CMA. Standard Method for Water Effluent Analysis, Foludex Press Ltd; 1995.
14. APHA. Standards Methods for Water and Wastewater Examination, 18th ed. American Public Health Association, Washington, D.C; 1992.
15. WHO. Guidelines for Drinking Water Quality; 2:1984.
16. FMEnv (Federal Ministry of Environment). National Guidelines and Standard for Water Quality in Nigeria. Technical Committee on Water Quality Criteria, Nigeria; 1992.
17. Ademoroti CMA. Environmental Chemistry and Toxicology. Foludex Press Ltd., Ibadan; 1996.
18. Klein L, River Pollution Vol. I – Chemical Analysis. Butherworths; Ibadan; 1958.

19. Ademoroti CMA. Effect of metallic toxicants on BOD measurements. J Biol Wastes.1988;24:259-265.
20. Francis Attiogbe. Comparison of membrane bioreactor technology and conventional activated sludge system for treating bleached kraft mill effluent. Afr J Environ Sci Tech. 2013;7(5):292-306.
21. Basheer Hasan Diya'uddeen, Wan Mohd Ashri Wan Daud, Abdul Aziz AR. Treatment technologies for petroleum refinery effluents: A review. Proc Safe Environ Prot. 2011;89(2):95–105.

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