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Low-Cost, Energy-Efficient and Carbon-Saving Dry Ice Air Conditioning System - A Possible By-Product of a Novel and Highly Cost-Effective Carbon Capture Technology

By Dilip K. De & Idowu B. Oduniyi

Abstract- To combat global warming and climate change, it is necessary to have technologies for the low cost capture of carbon dioxide (CO2) and the associated toxic components of the flue gas emissions from industries and for the low-cost storage and utilization of the captured CO2. This paper presents a brief description of a new technology for emission capture (NTEC) to capture nearly 100% of the CO2 from industrial emissions in the form of liquefied CO2 and dry ice, very cost effectively, at -$14 to $23 per ton of CO2 captured, depending on whether the power is generated by coal or natural gas and the CO2 concentration in the flue gas. The negative sign means the capture generates additional auxiliary energy for the industry. NTEC is patented in the USA (No. 10670334 B2 June 2, 2020). Using dry ice that could be abundantly available with NTEC, the proposed future technology of a dry ice air conditioning system is presented. Assuming that dry ice is not more than $80 per ton with NTEC, then, for air conditioning a house of area 256 sq. m. (the inside temperature maintained 24 hrs 7 days/wk at 70 F, while the outside temperature is at 102 F for 12 hrs), it would save $160 in a hot summer month.

Keywords: emissions from industries, novel technology of emission capture, carbon capture, environmental pollution and climate mitigation, lowest energy and cost of capture, dry ice air conditioning, cost and carbon saving.

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Dilip K. De α & Idowu B. Oduniyi σ

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Keywords: emissions from industries, novel technology of emission capture, carbon capture, environmental pollution and climate mitigation, lowest energy and cost of capture, dry ice air conditioning, cost and carbon saving.

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I. INTRODUCTION

a) *Carbon emission and capture*

Electric power plants, and cement and steel industry facilities, release flue gas (FG) that contains a large amount of pollutants, along with hot steam and unreacted nitrogen. The pollutants include fly ash, carbon dioxide (CO2), the associated toxic components (ATCs), such as nitrogen oxides (NO_x, x = 0.5,1,1.5,2,2.5), sulfur oxides (SO_y, y = 2,3), mercury (Hg) and its oxides, oxides of some other metals, acid vapors, volatile organic compounds (VOCs), soot, and particulate matter (PM) [1,1a-g]. With the existing state of the art, clean energy technologies' capture of the polluting components and CO2 is very costly and materials intensive [1-45, 45a-w].

These pollutants cause environmental damage and contribute to global warming. Literature abounds on the nature of these emissions and their effect on health [2a-g] and the environment [1- 45a], including ocean acidification [45b]. There is also literature on the current state-of-the-art technologies for capturing these emissions, and the cost implications to control the emissions in part or in full [1-45]. By studying all this literature [1-61], we find that:

1. The emission capture technologies developed so far are still quite expensive [23,24,25,45h,50], and 100% capture of the components (e.g. CO2, NOx, SOx, CO, Hg) is still not possible.
2. The technology for storing CO2 under high pressure in an empty coal or oil field [45a-h, 55, 1b-1g] is still quite expensive, and leakage into the atmosphere is a possibility. It involves compression to high pressure (2500 to 3000 psi) and passing through hundreds or thousands of miles of pipelines into underground geological formations [5a-h]. The stored CO2 may be mixed with impurities, and rapid utilization of the stored or captured CO2 is not possible. The oldest power stations may be uneconomical to retrofit with modern amine scrubbing technologies. The cost of capture of gaseous CO2 by amine scrubbing still ranges between $40 and $61 per ton of CO2 captured.

3. Various technologies are used to capture carbon dioxide from the air, an industrial source or a power plant flue gas. These include absorption, adsorption, chemical looping, or membrane gas separation technologies [45c]. The leading carbon capture technology uses various forms of amines [45a-f]. Even though modern CO2 capture technologies could reduce the CO2 emissions to the atmosphere by approximately 80- 90%, they increase the cost of electricity by an additional 21-91%. According to experts, the additional increase in delivery cost would put a severe burden on consumers. The cost of direct carbon capture by sucking carbon directly out of the air - by using fans and absorbing it into solutions of Ca(OH)2 or KOH and then regenerating CO2 by heating the solutions - has fallen from $600 to $98-$234 per ton. It is still too expensive to be employed on a large scale.
4. With amine-based solutions for CO2 removal, SO2 must be removed by techniques such as flue-gas desulfurization (FGD), to avoid potential reactions with the amine-based solutions. However, techniques to remove NOx are often not employed to minimize the capture cost. The carbon capture results in an energy penalty of 15-25%, depending on the type of carbon capture technology employed. This leads to additional emissions of CO2 and also of NOx and PM [45g].
5. There are secondary pollutants from the chemical-based emission capture technologies developed so far, like the nitroso compounds in amine scrubbing of CO2 [60], which are carcinogenic.
6. Because of the high cost, as of 2019, there were only 17 operating carbon capture and sequestration (CCS) projects in the world, capturing 31.5 million tons of CO2 per year, of which 3.7 million tons is stored geologically [45e].
7. According to an organization which promotes CCS, it will cost $120-$140 per ton of CO2. This will add from $168 to $196 to the cost of a MWh of coal generation [61].

b) *Need for a new carbon capture technology*

Thus, we see that there is a need for research on the development of technologies for the low-cost capture of CO2 and the ATCs of the FG emission and the storage of CO2 and its utilization. This paper presents a brief description of a new technology for emission capture (NTEC) which would capture industrial emissions, CO2 and the ATCs, at a nearly 100% rate, using less energy and at a cost lower than the lowest of all existing technologies [5]. This paper's main thrust is on very cost-effective storage of the vast amount of dry ice that would be available using NTEC in the future and the use of the dry ice for future air conditioning to save carbon and consumers' cost. References for sections I.1 and I.2 are given in Appendix C. NTEC has been patented in Jun 2, 2020[US patent No. 10670334] by the authors.

Modern refrigeration and air conditioning (AC) systems consume a significant amount of electric energy [1-3], generation of which gives rise to emissions of CO2 and many toxic components which not only contribute to global warming but also have many environmental effects ([2a-g] of Appendix C). The cost of running the dry ice AC is analyzed and compared with current AC, and a method of storing the dry ice that would be available with NTEC is described. The carbon saving from the future use of such air conditioning systems is discussed. Finally, the positive environmental effect it would have in the future is discussed.

II. A VAST AMOUNT OF DRY ICE TO BE AVAILABLE USING NTEC

Below we describe our novel technology, NTEC, to capture CO2 and the other components of the FG (Fig. 1). This method is very cost effective, does not require the use of any chemicals, and only needs a fixed amount of water which can be used repeatedly. The basic principle of this new technology has been intensively studied by the authors [5]. We describe below the key novelties of NTEC over other emission capture technologies. A brief description of the key principles and methods involved is given in Appendix D.

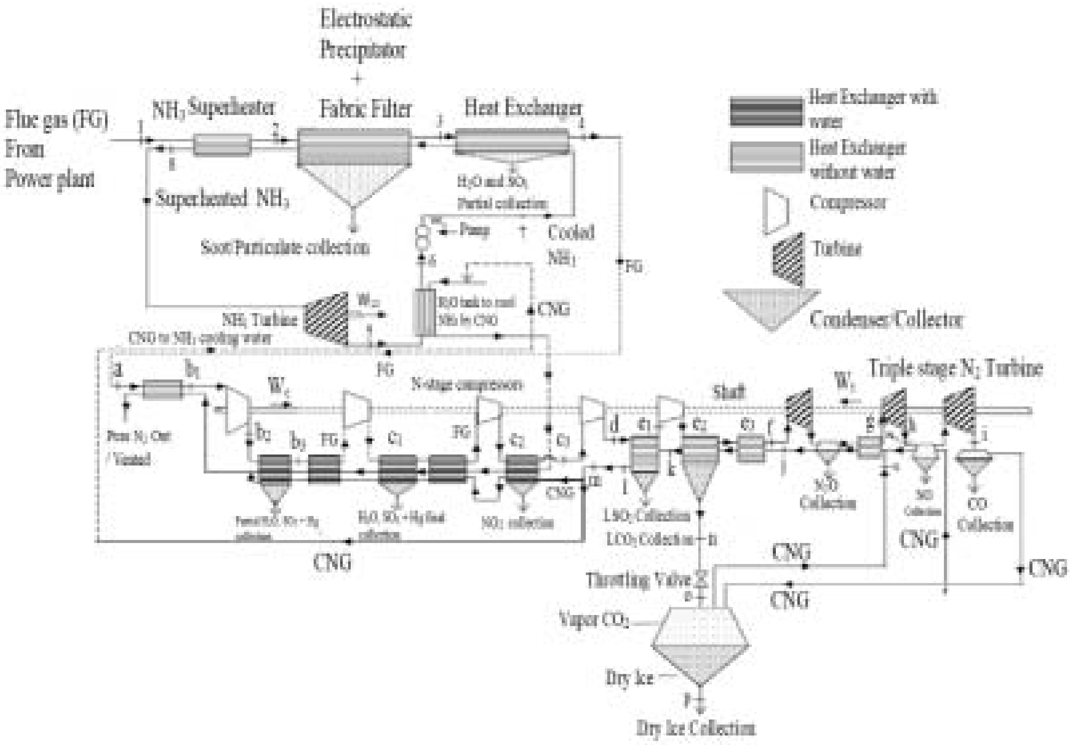

Fig. 1: Schematic diagram of the equipment based on NTEC to capture CO2 and the toxic components of the FG from power plants most cost-effectively with very high energy efficiency (244 MJ per ton of CO2 from a coal power plant and -237 MJ per ton of CO2 from a natural gas power plant. The US patent No. 10670334 B2, with 18 sub-claims for the above equipment, and 19 process claims have been issued on June 2, 2020.

a) Key Novelties of NTEC over other Cryogenic Technologies

Fig. 1 schematically describes the methods of NTEC that include the following novelties: (i) generation of auxiliary power (AUP) from the heat of the FG, in order to lessen the dependence on energy from the main output of the power plant, and thus also cooling the FG to the ambient temperature before compression; the theory of this can be seen in detail in the authors' US patent [5]; (ii) isentropic compressions by 15 compressors, each compression being at increasing steps of 1.8 to 2 bars, and cooling the compressed FG after each compression by cold nitrogen gas (CNG), until the FG reaches ∼27 bars pressure at temperature ∼11 C in a special heat exchanger [5] (at e2 in Fig. 1), where the CO2 of the compressed FG condenses fast (Fig. 2) to liquefied cold CO2 (LCO2 in Fig.1); this reduces the net compression work more than a single compression and cooling (see Appendix E), and to a value much lower than that of previous workers [23b-d,24]; LCO2 can be converted to dry ice as needed (Fig.1); (iii) further cooling the FG (after capture of CO2) in a heat exchanger (at e3 in Fig.1), and generating CNG (at -195 C to -194 C) from the unreacted nitrogen gas by three-stage turbine expansion (at points f-g-h-i in Fig.1); (iv) cooling the FG in heat exchangers (between points a and i in Fig. 1) by the CNG for very fast heat exchange between the flowing FG and the CNG; (v) utilizing the turbine expansion work for compression of the FG using a shaft (Fig.1); (vi) using no chemicals and only a fixed amount of water that is reusable for many years; (vii) capturing CO2 (with purity > 99.99%) in the form of a cold liquid after capture of fly ashes, soot, SO3, NO2, H2O, each separately (for details, see Ref. 5); (viii) capturing N2O, NO and CO, each separately, during the three-stage turbine expansions after capture of CO2; (ix) freezing the dry ice by CNG and collecting dry ice in air-tight conditions; (x) taking measures all along to prevent choking of the compressors during compressions of the FG and the capture of components; (xi) all capture being accomplished using a single piece of equipment that can be fitted to a new power plant and retrofitted to an old power plant; (xii) capturing products that all have industrial demands; (xiii) NTEC does not require any storage for cryogens as required by previous works [34].

The processes involved in the capture are given in detail in Appendix D. The theories of energy of capture per ton of CO2 (EC) are provided in Appendix E. Further details can be seen in Ref. 5.

As discussed in section II.3, and seen in Tables A & B(columns A3 & A4), NTEC requires a net EC much lower than the lowest EC by all existing state-of-the-art cryogenic[see Appendix E] and chemical-based technologies [23c-31,33]. It my be noted from column A2 of Table A and Refs. 23c-31 that our technology would provide a much lower cost of CO2 capture even if we eliminate AUP. With AUP, this is the only technology that would enable capture of CO_2 and the ATCs from a natural gas power plant (NGPP) without requiring any energy from the main power output and yet would deliver extra energy to the grid after capture, if the FG exit temperature is 250 C or slightly higher and the dry mass CO2 concentration is more than 12.5%. For a higher temperature of the FG, the temperature can be brought down by a standard air-preheating technique and a combined power and heat cogeneration technique [32].

b) Comparison of NTEC with State-of-The-Art Co_2 Capture Technologies

With NTEC, depending on the FG temperature and whether coal or natural gas is used for power generation, CO2 can be captured at a low cost (-$14.5 to $22.5 per ton of CO2 captured (Table A)) from the FG. The negative dollar value indicates extra energy generated (profit) during capture of CO2 from a NGPP using NTEC when the CO2 dry mass concentration (DMC) in the FG is more than 12.5%. Dry ice has many applications which could be further extended with NTEC. There is no recurrent expense of materials for the capture of emissions and most of the toxic components of the FG are captured at no additional cost. Unlike current state-of-the-art capture technologies [23c-31], there is no secondary emission with NTEC. Many secondary emissions are carcinogenic.

Using high pressure, 100-200 bars, Baxter et al. [23c] found the minimum EC for liquefaction to be 700 MJ per ton of CO2 for an oxyfuel combusted power plant (98% CO2 concentration by weight). The corresponding energy with NTEC would be 191 MJ if we do not use AUP and turbine work (TW). With AUP and TW, these would produce surplus energy with our method. Now, in a simulated model of carbon capture from an oxyfuel combusted FG, Toleuova et al. [24] found that the minimum energy needed was 0.18 MWh, which is equivalent to 648 MJ per ton of CO2.

According to Keith et al. [26], using the latest technology of capturing CO2 directly from the air (using alkali to absorb it and then heating the alkali to regenerate it), the energy cost is approximately 8800 MJ of natural gas, or 5250 MJ of natural gas and 366 kWh of electricity per ton of CO2 captured. The levelized cost now ranges between $94 and $232 per ton of CO2 for direct air-capture. Faishi et al. [27] gives an excellent review of all the studies of the cost of direct CO_2 capture from the air and the lowest cost (5526 MJ/tCO_2) exceeds by far our high cost of carbon capture, 1276 MJ/tCO2 from a coal power plant, and 341 MJ/tCO2 from a natural gas power plant (Table A, columns A3 & A4). Direct CO2 capture from the air has been increasingly discussed as a climate change mitigation option. However, even with the latest developments, the cost is still quite high.

Zanganeh et al.'s experimental studies [28] showed that the cryogenic technique is most cost effective when the feed gas is available at high pressure and high concentration as in the FG of oxyfuel combustion. For gas mixtures with high initial pressure and high CO2 concentration (90% in a CO2/H2 mixture), Xu et al. [29] studied a technique comprising a two-stage compression, two stage refrigeration, and two-stage separation with recovery of cryogenic energy, and found that CO2 can be captured at 395 MJ/tCO2. NTEC offers much lower EC (maximum 188.5 MJ/ton) for oxyfuel combustion without TW and without AUP (100% CO2 concentration, Table A). With TW and AUP the EC is negative, meaning generation of excess energy.

Song et al.'s studies [30] revealed that under the optimal temperature and flow rate, CO2 recovery of the cryogenic process can reach 96% with 1500 MJ/tCO2 energy consumption. Tuinier et al. [31] found that more than 99% of CO2 could be recovered from a FG containing 10% (v/v) (15% DMC) CO2 and 1 % (v/v) H2O with 1800 MJ/tCO2 energy consumption, using a novel cryogenic CO2 capture process that uses dynamically operated packed beds. Comparing results (700 MJ in column A3) & (-237 MJ/tCO2 in column A4) (Tables A & B), one can see that our technique surpasses all the above mentioned technologies. Thus, our patented technology with no secondary emission is superior to previous technologies also in terms of the cost of capture of CO2. Unlike ours, they have not focused on the dependence of the capture energy on the CO2 concentration in the gas mixture. Unlike current SOAs NTEC has potential to produce power with net zero emission.

c) Amount of Dry Ice that can be Captured by NTEC

Considering the case of the total energy generation, 1.4×10^{18} J, in the UK in 2010 and the analysis by Dr. Clifford Jones of the total CO_2 emitted [5a], and considering the fact that NTEC is capable of capturing at a near 100% rate, the total dry ice that can be captured is 587 million tons if the power is generated by coal, and 198 million tons if the power is generated by natural gas [5]. Even utilization of only a 50% capture rate would contribute significantly towards the mitigation of climate change. The vast amount of dry ice thus captured would enable the use of dry ice refrigeration and air conditioning that would contribute further towards climate mitigation (see section III).

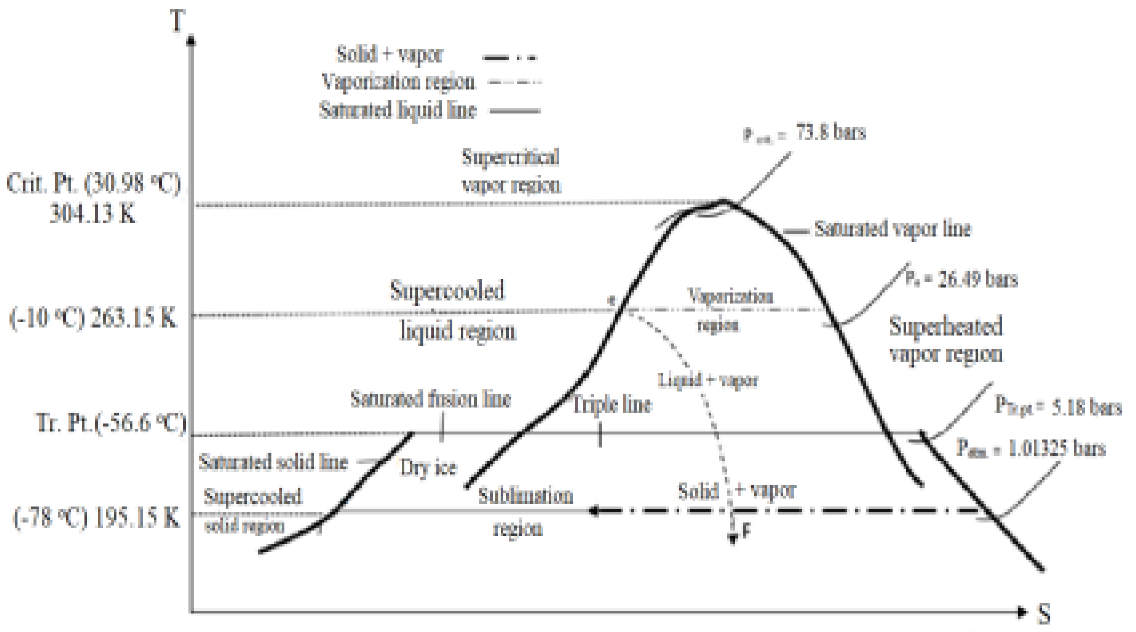

Fig. 2 [5]: The temperature entropy of CO2 for production of liquefied CO2 and dry ice using the new technique

Table A: Modeled values of power plant energy (EC) needed (and the cost) to capture 1 ton of CO2 in liquid form (ELCO2), and most of the ATCs (separately), with different CO2 concentrations under various capture conditions of NTEC, using 15 compressors. (Proprietary of Sustainable Green Power Technologies (SGPT) and US Patent 10670334 B2 dated June 2, 2020)[!]

DMC of CO2 (%)	DMC of N2 (%)	A1	A2	A3 Coal		A4 Natural Gas	
		Energy (MJ)		Energy (MJ)	Cost* ($)	Energy (MJ)	Cost* ($)
10	90	2861	1744	1268	23	333	6
15	85	1876	1174	700	12	-237	-4
20	80	1378	879	403	7	-532	-9
22	78	1244	805	329	6	-606	-11
25	75	1082	710	244	4	-701	-$13
30 100[!!]	70 0	883 188.5	594 ---	118 --	$2 --	-817 --	-$14 --

[!] We assume 35% efficiency of power generation, and that the exit exhaust FG with temperature between 250 C and 300 C can raise the ammonia temperature in the auxiliary power generator to 200 C. If the temperature of the exit FG from the power plant is higher than 300 C, it can be brought down using combined heat and power [32] and an air preheater (APH). See Appendix E for methods of calculations of EC.

DMC (Dry mass concentration) - the percentage of mass in the mixture after H2O, SO3, NO2, SO2, soot, VOCs, etc. are removed from the FG. Vol(%) =28xDMC/(44-DMCx0.16) The corresponding volume concentration is slightly more than half.

A1- Energy from a power plant needed to liquefy 1 ton of CO2 (ELCO2) without turbine work (TW), without auxiliary power (AUP), but with cooling by an external liquid nitrogen source (ELNS)

A2- ELCO2 with TW, with cold N2 gas cooling (CNG), but without AUP and without ELNS

A3- ELCO2 with TW, with AUP, with CNG, but without ELNS

A4- ELCO2 with TW, with AUP, with CNG, but without ELNS

[!!]With oxyfuel combustion, the DMC is 100%. For this DMC tentative values are given in columns A2,A3 &A4. Investigation on correct values for these columns are continuing.

*The cost is evaluated using the cost of electricity at generation point, $0.0644/kWh [Table 3 of Ref. 33]. For other concentrations, and for much lower FG temperatures, we are collecting data to compute the energy values. The values with finite AUP are expected to be significantly less than those with no AUP.

Table A (Recalculated): Modeled values of power plant energy needed (and the cost) to capture 1 ton of CO2 in liquid form (ELCO2), and most of the ATCs (separately), with different CO2 concentrations under various capture conditions of NTEC, using 15 compressors. (Proprietary of Sustainable Green Power Technologies (SGPT) and US Patent 10670334 B2 dated June 2, 2020)[!].

DMC of CO2 (%)	DMC of N2 (%)	A1	A2	A3 Coal		A4 Natural Gas	
		Energy (MJ)		Energy (MJ)	Cost* ($)	Energy (MJ)	Cost* ($)
10	90	2868	1752	1276	23	341	6
15	85	1876	1173	697	12	-238	-4
20	80	1379	883	407	7	-528	-9
22	78	1244	804	328	6	-606	-10
25	75	1082	710	234	4	-701	-12
30 100[!!]	70 0	883 189	594 189	118 -287	2 -5	-817 -1292	-14 -23

Table B: Modeled energy (EC) from a power plant needed to capture CO2 at different concentrations in the FG exiting a power plant and under various capture conditions. The lowest energy is in columns A3 & A4. All are the same as in Table A except 10 compressors are used

DMC of CO2	DMC of N2	A1	A2	A3 Coal	A4 Natural Gas
		Energy (MJ)	Energy (MJ)	Energy (MJ)	Energy (MJ)
0.10	0.90	2912	1796	1320	385
0.15	0.85	1903	1200	724	-211
0.20	0.80	1400	899	423	-512
0.25	0.75	1098	726	250	-685
0.30	0.70	896	607	131	-804

III. DESIGN OF THE NEW DRY ICE REFRIGERATION AND AIR CONDITIONING SYSTEM WITH DRY ICE THAT CAN BE ABUNDANTLY AVAILABLE WITH NTEC

The new dry ice refrigeration and air conditioning system is very simple compared to the existing chlorofluorocarbon-based systems. It primarily consists of a very well-insulated structure BRW (outside the main house) of inside dimensions 2.3 m x 2.3 m x 2.3 m, at the center of which there is a metal box (MB) made of aluminum plates of size 0.7 m x 0.7 m x 0.7 m (see Fig. 3a). The box MB is surrounded on all sides by slabs of dry ice (DRI in Fig. 3a) of total thickness 0.3 m. The DRI are surrounded by very good insulation (INS in Fig. 3a) made of Styrofoam (or polyurethane) and aluminum foil (for reflection). The insulation thickness is 0.5 m. The mass of the dry ice would be adequate to last for three months, assuming that the thermal insulation is good enough. There is also an additional layer of insulation of thickness 0.35 m outside and all around BRW. The metal box is connected to the house with two tubes one at the top and the other near the bottom. The bottom one conveys cold air to the house and vents it at the top of the house. The top one (HA in Fig. 3a) conveys warm air from the top of the house to the top of the metal box. The fans needed for this circulation of cold and hot air could be run by a small solar panel or a battery or even electric power and are connected to the automatic control system (CS) which sets the temperature of the house. The tubes also contain CO2 sensors to prevent leakage of CO2 into the main house. For efficient cooling, the structure of the metal box MB is as shown in Fig. 3b. The horizontal metal fins connect the opposite walls of the box with alternate gaps as shown. The walls of the box MB are kept in constant contact with the dry ice slabs through a spring system (not shown in Fig. 3a) attached to BRW. The sublimated CO2 is vented outside the house by a tube (not shown in Fig. 3a). The tube collects the CO2 from the top side of BRW and vents it to the outside near the ground in a garden.

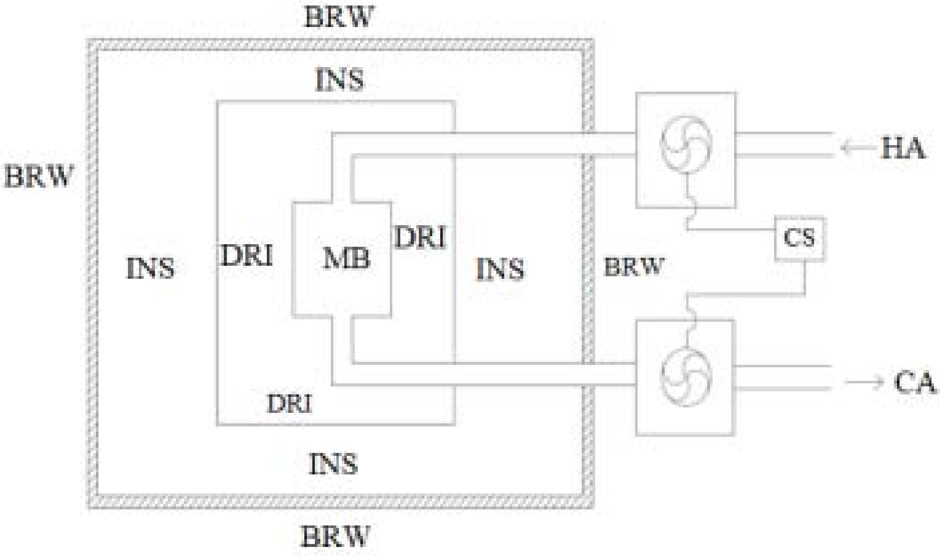

Fig. 3a: A schematic of the future dry ice refrigeration and air conditioning system

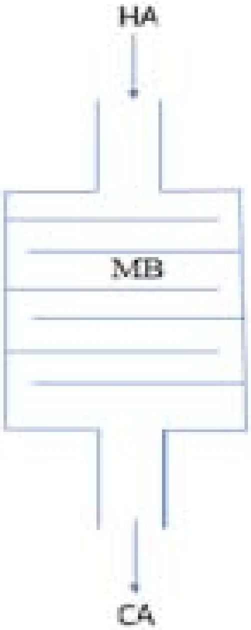

Fig. 3b: Internal structure of the box MB in Fig. 3a to cool hot air efficiently. It contains alternate metal fins. This arrangement provides efficient cooling of the hot air (HA) from the house and generates the cold air (CA) that circulates

a) *Cost of Running the Dry Ice Air Conditioning and Comparison with Conventional Ac*

We consider a house of 256 sq. m. with internal height 4 m and with the walls and the roof covered with insulation 0.75 m and 1.5 m thick respectively. We assume that the insulation has effective thermal conductivity (0.025 W/mK) of that of rigid expanded board made of polyurethane [6]. We consider the outside temperature to remain at 102 F for 12 hrs of the day and the internal temperature of the house to be kept at 70 F. We assume that every day 25% of fresh air at 102 F enters from outside. Calculation (Appendix A) shows that the monthly consumption of dry ice will be 800 kg, if the BRW of Fig. 3a is well insulated. The consumer cost of this dry ice will be $60 per month. With conventional air conditioning a 5-ton AC [1-3] needs to run for 12 hrs a day (total) and it would consume 1800 kWh of electricity, which in Texas would cost at least $216 per month at $0.12 per kWh. Besides the cost saving of $152 per month during the summer time, it would yield a carbon saving of at least 892 kg if the entire power is generated from coal (0.94 kg CO2/kWh) and 190 kg if the entire power is generated using natural gas (0.55 kg CO2/kWh). Without NTEC, such cost and emission savings would not be possible using dry ice available at $1000 per ton [4] with current technologies.

Calculations based on a case study (Appendix A and Appendix B) show that if the inside air is at 102 F, it can be cooled to 87 F in 3 hrs, with a cool air flow rate of 0.42 kg/s (Appendix B) from MB (Fig. 3a). In about 6 hrs the house will reach 70 F (controlled by thermostat sensor in the middle of the house). Once at 70 F, the needed cool air flow rate will be 0.075 kg/s into the house to compensate for the heat flow from outside at 102 F. The internal wall temperature can be at 75 F.

Thus, substantial savings of money and carbon can be achieved using the dry ice air conditioning if the CO2 is captured using our technology. Both the new technology for emission capture, NTEC, and the dry ice air conditioning technology can self-sustain without any carbon tax or incentives from the government. Such sustainable technology can go a long way in ensuring clean energy and a green environment at the lowest cost. Moreover, abundantly available dry ice at such low cost can expand industrial uses of dry ice and the pure CO2 that can be obtained from it.

b) *Storage of Vast Amounts of Dry Ice that Can Be Produced In The Future From Industrial Flue Gas Using NTEC*

As discussed, the current technology of sequestrating gaseous CO2 in empty geological formations is quite expensive [1-45a-h in Appendix C]. Below we describe a simple storage technique for the storage of CO2 in the form of dry ice that could be captured in vast amounts using NTEC in the future.

Dry ice can be stored if it is highly insulated. We propose that a structure (Figs. 4a & 4b) 540 m x 540 m x 25 m in which compressed dry ice slabs (5 kg to 20 kg weight) will be stacked to a total volume of 500 m x 500 m x 10 m(height). This is surrounded by a gap of 10 m on each side of the square and 5 m on the top, with a thick insulation of 10 m width, 15 m height on all sides. Figs. 4a & 4b show a schematic view of the horizontal and vertical sections of the storage structure. On the top of the structure there is a 5 m air gap on top of which there is the 5 m thick insulation (Fig.4b). The insulation is made of 5 cm to 10 cm (thickness) x 2 m x 2 m slabs of Styrofoam (heat conductivity, k = 0.033 W/mK) or rigid expanded board of polyurethane (k = 0.025 W/mK) [6,25], sandwiched in between shining smooth aluminum foil. The 10 m thick insulation is made by pressing together such insulating units. One can use more insulating layers of polystyrene (heat conductivity 0.02 W/mK), if needed. A simple calculation of heat transmission shows that the maximum annual sublimation (in closed confine) would be 253 tons (1 ton = 1000 kg) if the outside temperature is 102 F for 12 hrs a day. (Now the structure of 500 m x 500 m x 10 m can contain dry ice of mass $\sim$ 3,750,000 tons). With occasional opening of doors, the losses should not exceed 1500 tons annually, if the insulation is kept as mentioned. Thus, more than 99.9% of dry ice can effectively be stored annually.

Using sunlight, the amount of CO2 released from dry ice can be controlled by adjusting the insulation (5 m thick) of the roof (Fig. 4b).

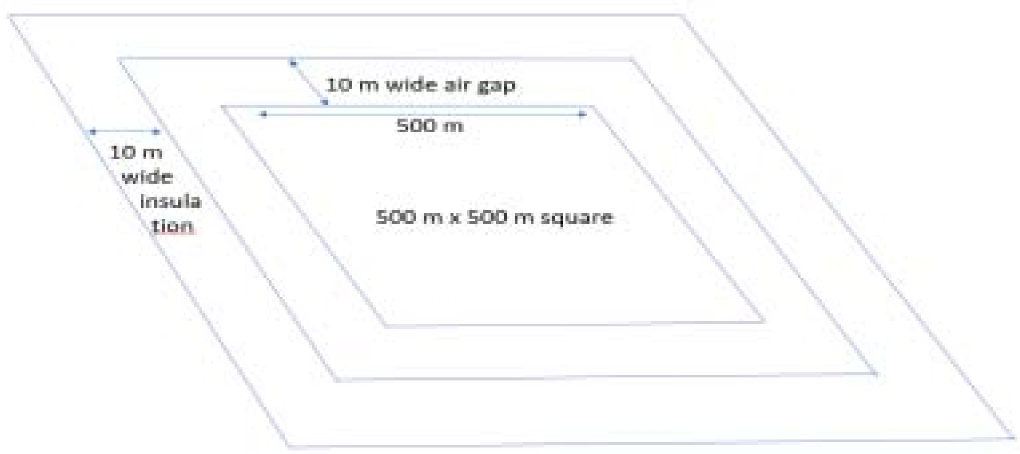

Fig. 4a: Horizontal cross section of the dry ice storage system

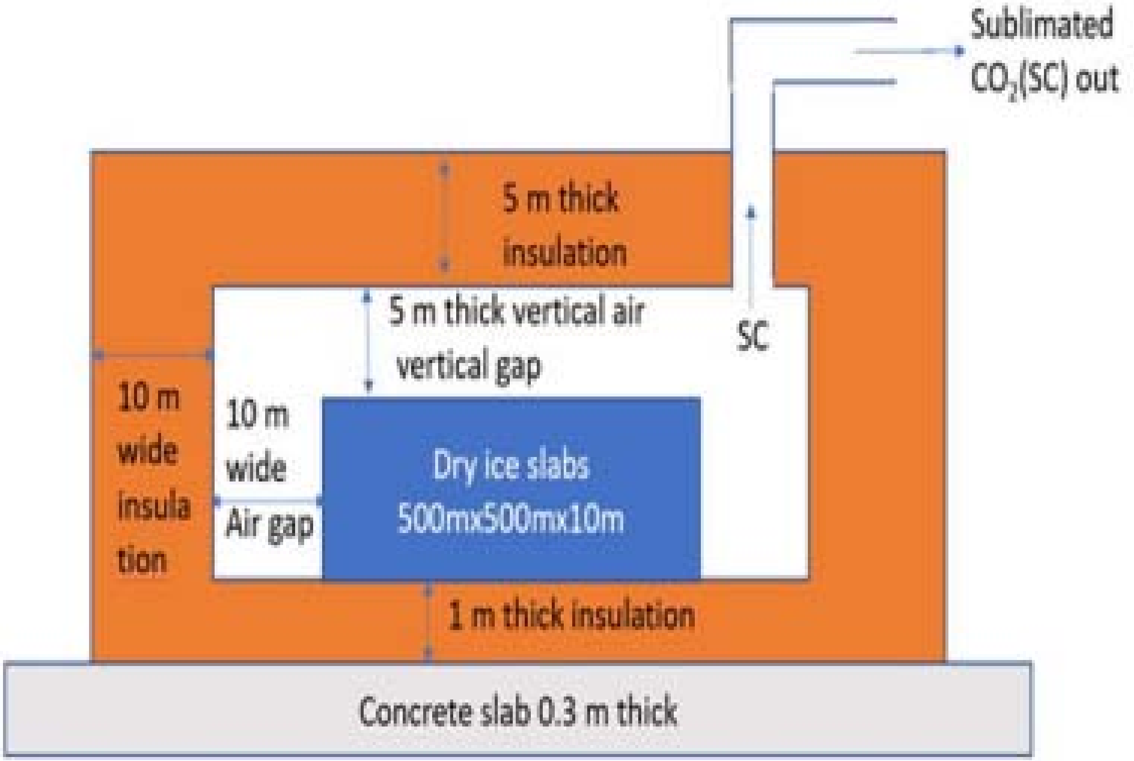

Fig. 4b: Vertical cross-sectional view of the dry ice storage system

c) *Recapture of Sublimated Co2 From Dry Ice Refrigeration And Air Conditioning Systems And The Storage Structure*

The sublimated CO2 from dry ice refrigeration and air conditioning systems and the storage structure can be quite pure if the initial small fraction of CO2 which would be mixed with air is flushed out. The sublimated pure CO2 can then be captured if needed for enhanced biodiesel production through accelerated growth of algae or jatropha [7-20] or for alcohol production [23a]. It can also be used for soft drink productions, if needed.

d) *Risks Involved in Dry Ice Refrigeration and Air Conditioning Systems*

The major risk involved in dry ice refrigeration and air conditioning systems would be the leakage of CO2 inside MB from the dry ice in BRW (Figs. 3a & 3b). This can be prevented by having sensors inside MB and in the tubes that convey cool air from MB to the main house. If leakage is detected then repairs can be made. The other risk is the leakage of CO2 out of the dry ice AC unit and a high concentration of CO2 in its vicinity. We assume that it will be dispersed into air with time.

e) *Environmental Impact of the Future Dry Ice Air Conditioning*

The total number of housing units in the USA in 2018 was 138 million. Assuming 87% of these have ACs, based on results given in section III.2, the carbon savings in a hot summer month would be $138 \times 0.87 \times 892 \times 10^6$kg = 107 million tons if power is generated by coal, and 23 million tons if power is generated by natural gas. Moreover, there will be savings of ATCs. Thus, dry ice AC would, in the future, substantially contribute towards a clean environment and the mitigation of climate change.

IV. Conclusions

Rigorous theoretical research with a case study (power generation in the UK in 2010) shows in patented technology that it is possible to capture CO2 at a cost - $14.0 to $23 per ton in the form of liquefied CO2 or dry ice, using the new technology, NTEC (Tables A & Table B). Considering all the benefits that the technology will yield, including the revenues that the captured products will bring, the net captured cost becomes either zero or negative. The negative dollar value (Table A) means that the carbon capture can turn out to be profitable without the sale of any captured products.

The new proposed dry ice AC system that can use the abundantly available dry ice with NTEC shows great advantage over conventional AC system. A case study of a 256 sq. m. house reveals that the system can save consumers $147 per month and carbon saving of at least 874 kg and 114 kg in a hot summer month, if the AC is run by electricity generated by coal and natural gas respectively.

Thus, such dry ice (solidified CO2) can be used in air conditioning with substantial cost and carbon savings if the industrial carbon emission is captured using the new technology, NTEC. This would help further achieve the objective of climate mitigation and reduce global warming.

ACKNOWLEDGEMENT

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APPENDIX A

Estimation Of The Cost Of Running A Dry Ice Air Conditioner Using NTEC For Capturing Industrial Emissions In A Case Study

To estimate the mass of dry ice needed for the air conditioning of a house we proceed as follows:

1. A house of inside area 256 sq. m. and internal height 4 m is considered. The volume is 1024 m^3. The density of air is 1.225 kg/m^3. Thus, the mass of the air in the house is 1254 kg. The specific heat of air is ~1 kJ/ kg.°C.
2. We assume that the outside temperature is 102°F. So, the total amount of heat to be taken out of the room on the first day is$\Delta Q1 = 1254$ kg x 1 kJ/kg. °C x 17.78°C = 22.3 MJ. We now assume that the house is well insulated and the furniture and equipment necessitates additional cooling of 20% of this heat reduction. Thus, total heat reduction on the first day is $\Delta Q2 = 26.8$ MJ.
3. We assume that the outside temperature remains at 85°F at night. Every night 20% of the air inside is replaced by fresh outside air. The amount of heat brought into the house from outside is $\Delta Q3 = 52$ MJ in a hot summer month.
4. We suppose that the house of area 256 sq. m. (total floor area) has four sides each of length 16 m and height 4 m (~13 ft) and has effective wall thickness of 75 cm with effective thermal conductivity of that of rigid expanded board of polyurethane (0.025 W/mK at polyurethane density 30 kg/m^3) [25]. We suppose that the ceiling (area 256 sq. m.) has an effective thickness of 1.5 m insulation. We assume that the outside temperature stays effectively at 102°F for 12 hrs in the daytime and at 85°F for 12 hrs at night and a central inner space of dimensions 12mx12mx3m stays at 70°F for 24

hours a day. In such a situation the total heat flow into the house is $\Delta Q4 = 381$ MJ in a hot summer month. This calculation is done by calculating the temperature at the inner wall and roof during equilibrium heat flow in the daytime and at night and then using a simple heat flow equation and calculating the total heat flow for the month through the walls and the roof during the day and during the night.

5. The additional heat penetrating the dry ice box (Fig. 3a) is $\Delta Q5 = 32$ MJ. This is calculated considering the total surface area of the dry ice slabs ($5x1.3^2$ m^2in the example considered). This will cause additional loss (over that due to (iii) & (iv) above) of dry ice by sublimation.
6. Thus, after the first day of cooling, the total heat flowing into the house (maintained at 70°F 24 hrs a day for 30 days) is$\Delta Q = \Delta Q3 + \Delta Q4 + \Delta Q5 = 52 + 381 + 32 = 465$ MJ for a hot summer month.
7. This heat would be removed by sublimation of dry ice which has latent heat of evaporation 578 kJ/kg at –78°C. Now its temperature will be raised from –78°C to 70°F (=21.1°C). Thus, the temperature change is 99.1°C. The specific heat of CO2 is 0.9 kJ/kg.°C. Thus, the total heat that can be removed by sublimation of dry ice is $\Delta H = 578 + 99.1x0.9 = 667$ kJ/kg.
8. Thus, the total dry ice that would be needed for cooling the house for the month is $\Delta Q/\Delta H = 465$ MJ/0.667 MJ/kg = 697 kg = ~700 kg.
9. Considering that with NTEC dry ice can be available to residential customers at $80 per ton (1000 kg), the total cost of dry ice with NTEC will be ~$56 for the month. Thus, dry ice AC, which is not affordable with current technology, can be easily affordable with NTEC.
10. An analysis of the net energy usage in a similar situation (running 12 hrs a day effectively) using conventional AC shows that a 5-ton AC is needed. With a 5 star AC (EER = 3.5) the power consumption for the month is 5kWx12h/dayx30days = 1800 kWh. With 12 cents per kWh in Texas this will cost the consumer $216 for the hot summer month [X] [XX] [XXX].
11. Thus, we see that the dry ice AC can save $216 – $56 = $160 in a hot summer month for a house of 256 sq. m.
12. As said before, conventional AC would require the generation of 1800 kWh of energy. CO2 emissions are 0.94 kg and 0.55 kg per kWh from coal power plants and natural gas power plants respectively. Thus, the carbon saving by the proposed dry ice AC, in generating the power for the conventional AC (5-ton) in a hot summer month, would be 1800x0.94 – 700 = 992 kg if coal is used, and 1800x0.55 – 700 = 290 kg if natural gas is used. This saving in carbon emission assumes that the sublimated CO2 is not captured back.
13. If the effective wall and roof insulations are 50 cm and 1 m thick respectively with the same materials as mentioned earlier, then the total heat flow through the walls and the roof into the house in the month is $\Delta Q4 = 1.5x381$ MJ = 572 MJ. The additional dry ice to be sublimated is 286 kg, to keep the house at 70°F for the month. The additional cost is $23. The net consumer savings would then be $160 - $23 = $137. The total carbon emission savings would be 992 - 286 = 706 kg, if the power is generated by coal. Thus, the dry ice AC would save considerable consumer cost and carbon emission.

14. If the effective wall and roof insulations are 50 cm and 1 m thick respectively with the same materials as mentioned earlier, then the total heat flow through the walls and the roof into the house in the month is$\Delta Q4 = 1.5x381$ MJ = 572 MJ. The additional dry ice to be sublimated is 286 kg, to keep the house at 70°F for the month. The additional cost is $23. The net consumer savings would then be $160 - $23 = $137. The total carbon emission savings would be 992 - 286 = 706 kg, if the power is generated by coal. Thus, the dry ice AC would save considerable consumer cost and carbon emission.

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Appendix B

a) *Determination of The Size of the Box Mb (Fig. 3b)*

We assume the box MB (Fig.3) to be a cube of side a (meters) and the area A of the metal plate is $A = a^2$. Let us assume that on the first day we want to cool the entire house by 16°F in 3 hours when the air inside (mass 1254 kg) is at 102°F. The specific heat of air is ~1 kJ/kg.°C. The rate of heat reduction (section (ii) of Appendix A) is 26800x(16/32)/(3600x3) = 1.24 kJ/s on the first day. Then the maximum heat flow from the walls and roof is 256 (102-86)(5/9)(0.025){1/0.75) + (1/1.5)} = 0.11 kJ/s, , assuming that the air inside is at 86°F during the 3 hours and the air outside is at 102°F. This figure (0.11 kJ/s) is somewhat higher than what one would get with rigorous calculations. Nevertheless it will better help the design of the box MB. So, the required heat flow rate out of the house is 1.35 kJ/s so that the house cools to 86°F from 102°F in 3 hours on the first day. This should be the cooling rate of the air inside the box MB. The accuracy of this model of the cooling rate depends on three factors:

We assume the box MB (Fig.3) to be a cube of side a (meters) and the area of the metal plate is $A = a^2$. To find the maximum rate of cooling needed, let us assume that on the first day we want to cool the entire house by 16°F in 3 hours when the air inside (mass 1254 kg) is at 102°F.

1. The conduction from hot air to dry ice through the metal in the box MB (Fig. 3) as hot air from the house is continuously pumped in. Calculation gives the heat conduction rate of $0.02x(38.9+78.5)x6A/(a/2) = 0.028a$ kJ/s.
2. We assume that as the hot air from the house is brought into the box, the center of the box is at 102°F, while the metal plate surface is at -78.5°C, since it is in contact with dry ice. The maximum radiation from the metal surface to the middle of the box is $\sigma((273 + 38.9)^4 – (273 - 78.5)^4)x6A = 2.73a^2$kJ/s ($\sigma$ = Stefan Boltzmann constant = $5.67x10^{-8}$ $W/m^2.K^4$; the factor 6 comes from the 6 faces of the box) We assume that the volume pump rate of air in the box is a^3/s. Then balancing the heat flow equation we get: $0.028a + 2.73a^2 = 1.35$. Solving this we get a = 0.70 m. We take the metal plate size as 0.7 m as mentioned earlier. Thus, if the air in the box MB (mass = 0.42 kg) is replaced every second (i.e. flow rate = 0.42 kg/s) then the entire house will cool in 3 hrs from 102°F to 86°F. Here we assume that the dry ice slabs are always kept in contact with the metal walls of the metal box with the use of a spring as mentioned earlier. The flow rate can be adjusted if needed to maintain the time of cooling at approximately 3 hours if needed.
3. Heat transfer coefficient as a function of air flow velocity witnin the box: While this factor is under modeling, we estimate that the effective time of cooling the house by 16°F would be somewhat less than 3 hrs on the first day. This is a pretty good rate of cooling. When the air mass attains 70°F, approximately after 6 hours, then to maintain this temperature while the outside is at 102°F, the cool air flow rate would be 0.076 kg/s. The temperature controller can be made to adjust the fan rates automatically.

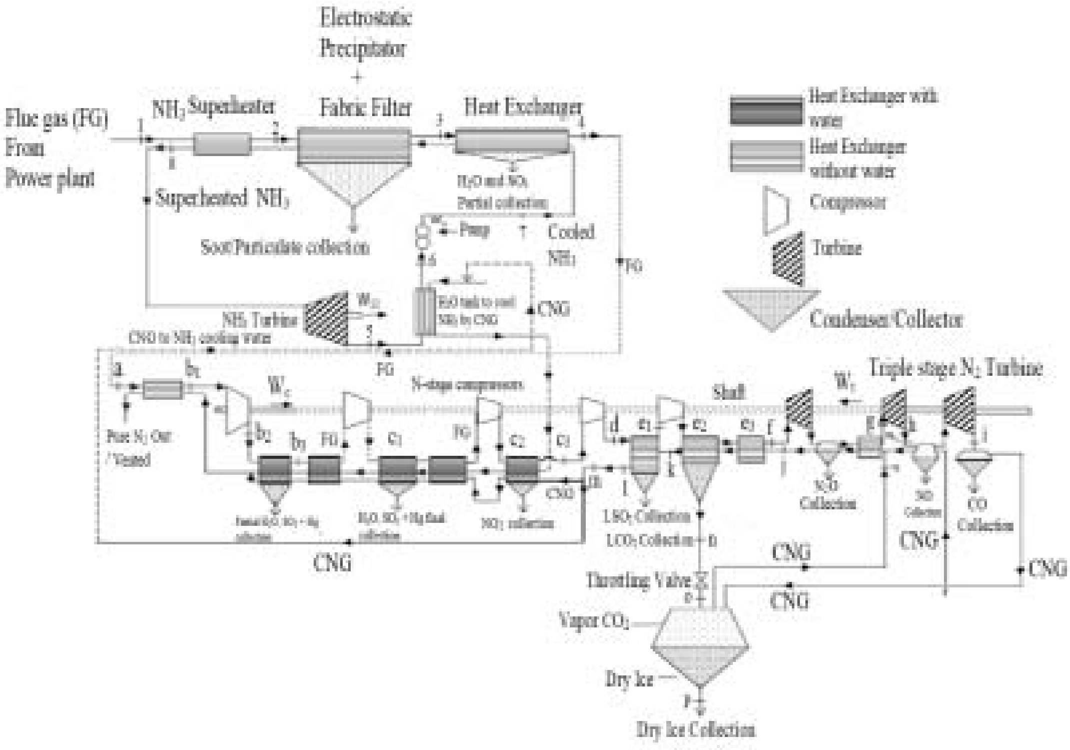

Fig. 1: Schematic diagram of the equipment based on NTEC to capture CO2 and the toxic components of the FG from power plants most cost-effectively with very high energy efficiency (244 MJ per ton of CO2 from a coal power plant and -237 MJ per ton of CO2 from a natural gas power plant. The US patent No. 10670334 B2, with 18 sub-claims for the above equipment, and 19 process claims have been issued on June 2, 2020.

Appendix C: References for Introduction 1.1.1 to 1.1.2.

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Appendix D [from US Patent- Dilip K. De and Idowu Oduniyi- Patent No. 10670334, B2, June 2, 2020; Ref.5]

Brief Description of Key Principles And Methods to Produce A Vast Amount Of Dry Ice from Industrial Flue Gas At A Very Low Or No Cost.

The key principles of the highly cost-effective industrial emission capture technology to capture carbon are described below in reference to Fig.1:

a. The FG (Fig.1) is brought down to a near ambient temperature by utilizing its heat content for auxiliary power generation by an ammonia (NH_3) superheater and a NH_3 turbine (Fig.1). The NH_3 superheater is kept in the second chamber of the ceramic filter chambers to absorb maximum heat of the FG [5]. The NH_3 after expansion is condensed in a water tank (at point 6 in Fig.1) cooled by cold nitrogen gas (CNG) (Fig.1). It is then circulated back by a pump to absorb heat of the FG and to repeat the cycle. After fly ashes are separated by ceramic filters (not shown in Fig.1), an electrostatic precipitator (ESP) and a fabric filter (FF), we employ N number of compressors (Fig.1) to compress the FG to a final pressure ∼27 bars, by N isentropic compressions at equal increments of pressure. N=15 reduces the compression work considerably (see Appendix E). However, N=10 can also suffice and would be easier to implement, compression work would be more than that for N=15.

b. The FG is cooled in a heat exchanger (H.E.) after each isentropic compression to a temperature ∼ 10℃ below the boiling point of the component to be captured in the specified H.E (Fig.1). The cooling is done by CNG generated in the process. Two types of H.E.s are used. Type I is used to cool the FG to capture components with a boiling point above 0℃, and Type II is used to cool the FG to capture components with a boiling point below 0℃. The H.E.s are specially built to ensure good thermal conduction between the FG and the cold surroundings created by the CNG. The inside of the H.E.s are coated with acid-resistant films that are tolerant to a wide range of temperature variations (-192℃ to 300℃) in terms of structural changes. These are discussed in US Patent Application No. 15915007.

c. See Ref. 5 for more details on the H.E.s.

d. After water vapor (H2O), sulfur trioxide (SO3), nitrogen dioxide (NO2), and sulfur dioxide (SO2) are captured (each separately (Fig.1)), the FG is finally compressed to 26.5 to 27 bars by the Nth compressor and passed through a H.E. at e2 in Fig.1 kept at ~ -20℃ to -25℃ so that it attains at least -10℃ rapidly when it passes through the H.E. This condenses CO2 to liquid CO2 fast (Fig. 2).

e. After step d, the compressed FG undergoes three-stage turbine expansions (TE) (f-g-h-i in Fig.1) whereby N2O, NO and CO are condensed separately, and finally CNG is produced which is recirculated to capture each component separately (Fig.1). For details of the capture processes of these components, see Ref. 5 by the authors. Liquid CO2 is converted to dry ice by isentropic throttling (Fig.2) into a flash chamber cooled by CNG to a temperature - 95℃. This also condenses the CO2 vapor to dry ice and solidifies more the dry ice already produced by throttling. There is a provision to collect the dry ice without any exposure of the flash chamber to the atmosphere [5]. The dry ice then can be collected and compressed into slabs for storage.

f. The TE work aids compression (see Appendix E) and reduces the net energy requirement for capture.

g. The calculations on the temperature of CNG produced by TE, the compression work by N compressors, the TE work received by compressors, the cooling requirements by CNG are all given in Appendix E. The thermodynamics of the auxiliary power generation are however skipped to save space. The interested reader is referred to section I.2 of Ref. 5.

Appendix E: Scientific Analysis of the Energy Requirement in the Processes Involved

Estimation of the compression work

Since CO2 and N2 are the major constituents of the FG from coal and natural gas power plants, and since in our technology nitrogen gas is finally cooled to ~2°C above its boiling point, and this cold nitrogen gas is used to condense most of the component gases of small percentages, it is sufficient to assess the energy required to capture the entire CO2 in the form of liquid and dry ice and the energy required to cool the nitrogen gas. From the methods discussed above, it is obvious that the net work of production of liquid CO2 from the carbon capture, ΔWnet, will involve the difference ΔW, where ΔW = the work input to the N-stage compressor (Wc) – the work output (WTE) of the nitrogen turbine during expansion – the auxiliary energy generated during the capture of CO2. This ΔWnet is the energy of capture (EC) given in Tables A & B. Below we explain how we obtain the values.

From thermodynamic analysis, the specific work done on an N-stage isentropic compressor, Wc, is given as

$$W_c = c_P\, T_x\, N\, [(P_y / P_x)^{(1/N)\,(\gamma-1)/\gamma} - 1] \qquad (1)$$

Where cp is the specific heat at constant pressure
Tx is the temperature at the inlet to each compressor stage
N is the number of stages
Py and Px are the final and initial pressures respectively
γ is the specific gas ratio.
The specific work output by a turbine, Wt, is given as

$$W_t = c_P\, (T_1 - T_2 \qquad (2)$$

where T1 and T2 are the inlet and outlet temperatures respectively.

Here
$$T_1 / T_2 = (P_1 / P_2)^{(\gamma - 1)/\gamma} \qquad (3)$$

for the isentropic expansion process.

By the energy conservation law, the work done on the compression of both the CO_2 and N_2 gases in the N-stage compressor is equivalent to the sum of the individual compressions, and for as much reduced compression work as possible, N (number of compressors) is taken as 15 in this study.

The properties of CO_2 are cp = 0.8464 kJ/kgK and γ = 1.288, the states are N = 15 stages, Py= 26.47 bars, Px=1.01325 bars. Then from Equation 1, the specific compression work on the CO_2 gas will be

$$W_c = (0.8464)\ (298.15)\ (15)[(26.12\ )^{0.0149} - \ 1]$$

$$= 188.51 \text{ kJ/kg}$$

(Tx is the temperature of the $CO_2 + N_2$ mixture at state b1 in Fig.1, and it is assumed to be ambient, i.e. 25°C).

Also the properties of N_2 are cp = 1.0404 kJ/kgK and $\gamma = 1.400$, the states are N = 15 stages, Py = 26.47 bars, Px = 1.01325 bars. Then from Equation 1, the specific compression work on the N_2 gas will be

$$W_c = (1.0404)\ (298.15)\ (15)[(26.12\ )^{0.019} - \ 1]$$

$$= 297.79 \text{ kJ/kg}$$

Estimation of the cold N_2 gas temperature and the turbine work output

For the temperature (T2) of the nitrogen gas at stage i in Fig.1 (i.e. exhaust temperature) to be achieved at the boiling point of nitrogen (-195.8°C) (77.35 K) at atmospheric pressure (1.01325 bars) for the capture of CO2 (boiling point of -191.5°C), the temperature T_1 at stage g in Fig.1 from equation 3 will be

$$T_1 = T_2\,(P_1 / P_2)^{\,(\gamma\,-1)/\gamma}$$

$$= 77.35 \text{ K } (26.471 / \ 1.01325)^{\ 0.2857}$$

$$= 77.35\ (2.5406) \text{ K}$$

$$= 196.52 \text{ K } (-76.63°\text{C})$$

The pressure at stage h in Fig.1 at the boiling point of NO -152°C) (121.15K) for the capture of NO under pressure will be

$$P_h = P_g\ (T_h / T_g)^{\,\gamma/(\gamma-1)}$$

$$= 26.49\ (121.15/196.52)^{\ 3.5}$$

$$= 4.87 \text{ bars}$$

Hence from Equation 2, the specific work output (Wt) by the three-stage turbine will be

Turbine Expansion Work Wt

$$W_t = 1.0404\ (196.52 - 121.15) + 1.0404\ (121.15 - 77.35) \text{ kJ/kg}$$

$$= (78.41 + 45.57) \text{ kJ/kg}$$

$$= 123.98 \text{ kJ/kg}$$

Estimation of the auxiliary power generated

The interested reader is referred to section I.2 on page 36 of Ref. 5.

Estimation of the net energy required for the capture of 1 ton of CO2

Using detailed thermodynamic analyses and applying the above mentioned process steps [5] to the case of the total power generated ($1.4\text{x}10^{18}$ J) in the UK in 2010 [5a], we find the following:

(a) Assuming that the anhydrous ammonia could be raised to 200°C (which is possible if the initial FG temperature is around 250°C to 300°C), then the energy generated by the auxiliary power generator could be 19.96% of the total energy ($1.4\text{x}10^{18}$ J) produced by the steam or gas turbine, assuming a ranking cycle of 35% efficiency for power generation. The calculation is based on the estimation of CO2 produced for the case study as carried out by Dr. Clifford Jones [5a] and detailed thermodynamic analysis as given in Ref. 5. If the FG temperature is such that the ammonia in the ammonia superheater can only be raised to temperature 100°C to 105°C, then the efficiency of auxiliary power (AUP) conversion from the heat of the FG is only 13.74%. Here, in the calculations of energy capture, we assume the 19.96% efficiency of AUP. We skip the details of these efficiency calculations and the specific processes involved to save space. The interested reader is referred to Ref. 5 for details.

(b) *Coal power plant.* Assuming the entire energy $1.4\text{x}10^{18}$ J under the case study is generated by coal then the total emission of CO2 is estimated to be 587 million tons. Our new technique is capable of capturing at a 100% rate, if needed. Thus, the auxiliary energy generated is 476 MJ/tCO2.

(c) *Natural gas power plant.* Assuming the entire energy $1.4\text{x}10^{18}$ J under the case study is generated by natural gas, then the total emission of CO2 is estimated to be 198 million tons. Our new technique is capable of capturing at a 100% rate, if needed. Thus, the auxiliary energy generated is 1411 MJ/tCO2.

An example of the calculation of the values of energy in Table A

In coal power plants the average constituents for 1.00 kg of dry FGs containing CO2 and N2 is assumed to be 0.25 kg for CO2 and 0.75 kg for N2. While in natural gas power plants the average constituents for 1.00 kg of dry FGs containing CO2 and N2 is estimated to be 0.15 kg for CO2 and 0.85 kg for N2 [Y] [YY].

Therefore, for 1.00 kg of dry FGs in a coal power plant, the compression work input for CO2 will be (0.25) kg x (188.51) kJ/kg = 47.13 kJ, and (0.75) kg x (297.79 kJ/kg) = 223.34 kJ for N2, given a specific compression work input of 47.13 kJ + 223.34 kJ = 270.47 kJ/kg for the mixture of the gases (0.25 kg CO2 plus 0.75 kg) N2 by the energy conservation law. Thus, for the capture of 1 kg of CO2, the compression work is Wc = 270.47/0.25 = 1082 kJ. For 1 ton of CO2, Wc = 1082 MJ (column A1 of Table A, for DMC=25%).

By the above method, the natural gas power plant will have a specific compression work input of 281.40 kJ/kg for the mixture of the gases. Thus, Wc = 1876 kJ/kg = 1876 MJ/tCO2 (Table A, column A1 for DMC=15%)

Since the specific work output of the turbine is 123.98 kJ/kg, the turbine work from the nitrogen in the FGs in a coal power plant is estimated to be (0.75) kg x (123.98) kJ/kg = 92.99 kJ, and that from a natural gas power plant is estimated to be (0.85) kg x (123.98) kJ/kg = 105.38 kJ.

Therefore, the net work input into the production of 0.25 kg of liquid CO2 at state n (Fig.1) from a coal power plant is estimated to be 270.47 – 92.99 = 177.48 kJ, which is equivalent to 709.92 kJ per kg of liquid CO2 at state n in Fig.1. This is shown in Column A2 of Table A for DMC=25%.

Also, the net work input into the production of 0.15 kg of liquid CO2 from a natural gas power plant is estimated to be 281.40 – 105.38 = 176.02 kJ. 176.02 kJ is the net compression work in NTEC per kg of FG containing 0.15 kg of CO2 and approx. 0.85 kg of N2 gas (i.e., the dry FG containing 15% CO2 gas), which is equivalent to 1,173.47 kJ per kg of liquid CO2 at state n. This is shown in Column A2 for DMC=15%.

We use the values of auxiliary energy as given above to calculate the net EC (ΔWnet) values. These are given for coal and natural gas in columns A3 and A4.

For N=15, using the above data we get Table A for the EC of CO2 with various dry mass concentrations (DMC). Similarly following the above theory we create Table B for N=10. It appears that N=10 would be a good choice since it would be easier and less costly to build the equipment of Fig.1. It is to be remembered that in NTEC we are mainly considering FG produced in coal or natural gas power plants that use normal air instead of pure oxygen for burning the fuel.

Cooling of the flue gas by the cold nitrogen gas produced in the CO_2 capture processes

Cooling the entire unreacted nitrogen gas of the FG to a temperature 1°C or 2°C above the boiling point (-196.5°C) of nitrogen using three-stage turbine expansions of the compressed FG initially at ~27 bars, and using the cold nitrogen gas thus produced to cool the incoming FG at various stages, and using only a fixed amount of water that can be repeatedly used, we find that the cold nitrogen gas cooled to -195°C is sufficient to cool the FG in various stages of capturing the component gases.

The heat gained by the cold nitrogen gas (assuming it is 75% of the FG; and assuming 10% H2O as steam and approximately 15% CO2 by volume) in rising from -195°C to the ambient temperature 25°C, is

$$H_N = 0.75.V.d_N.C_N(25-(-195)) = 0.75.V.d_N.C_N.220 = 165x1.2(kg/m^3)x1.03(kJ/kg.K) = 204\,kJ/m^3.$$

d = density and C = specific heat in gas-form.

The heat lost by the FG in the first cooling to temperature 45°C(step 7) is

H1 ≅ (0.75. dN.CN. + 0.1.dH2O(vapor).CH2O(vapor). + 0.15. dCO2(gas). CCO2(vapor)).(70-8) +(0.75. dN.CN. + 0.15. dCO2(gas). CCO2(vapor))(8-(-18)) +(0.75. dN.CN.)x(-10-(-55)) +(0.75. dN.CN.). (- 89-(-108)) + (0.75. dN.CN.)(-155-(-165)) = 1.2x62 +1.13x26+0.924x(19+45+10) = 172 kJ/m^3.

Thus, H1 is significantly less than HN, a condition necessary and sufficient to carry out all the cooling described in NTEC by only the cold nitrogen gas as said earlier.

After the auxiliary power generation, the temperature of the FG may be in the range 25°C to 70°C, depending on the initial FG temperature. We assume 70°C here.

NTEC captures CO2 from power plants at a cost much lower than the lowest cost of capture by current state-of-the-art technologies (CSOAs)

For example, a typical concentration in the FG from a coal power plant is 13.5% CO2 and 74% N2 by volume. This corresponds to a CO2 DMC of 22%. From Table A, column A3 we see that the EC is 329 MJ per ton of CO2. This is within 5% to 10% of electricity output per ton of CO2 emission. The energy penalty with CSOAs for oxyfuel combustion (DMC=100%) is 20% [YYY].

The energy penalty with CSOAs can easily reach 40% [YYYY]. With NTEC, as discussed earlier in section II.3, the maximum EC for oxyfuel combustion (Table A) is 188.5 MJ/ton of CO2 captured. If the energy is tapped from the output of a supercritical pulverized coal power plant [YYYYY], the CO2 emitted per MWh is 0.746 ton/MWh. This amounts to the maximum energy penalty by our technology, ~3.9%, without AUP (Table A). With AUP, there would be an energy surplus (not calculated in Table A). For a natural gas power plant a typical FG concentration corresponds to a CO2 DMC of 15% and the EC is –237 MJ, meaning that extra energy is generated during the capture. It should be noted that NTEC does not involve any additional cost of chemicals as used in current CSOAs. Thus, the cost is lower than the lowest cost of capture by CSOAs.

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A Close Examination of the Detergent Destruction Method for Aerobic Treatment of Wastewater High in Detergent (WHD) Content

By K N Tan

Abstract- Detergent wastewater has to be treated to prevent water pollution, especially for the reclamation of large quantity of laundry wastewater for reuse. A detergent destruction method removes detergent by using it to breakdown the activated sludge so as to prevent foaming when aerated in an SBR. Many research studies had reported methods and effects of increasing sludge reduction. A close examination of detergent destruction method to treat WHD has agreed well with the literature that activated sludge disintegration by consuming the detergent in wastewater has significantly reduced the activated sludge amount by mixing with and without aeration. The high rate of sludge reduction with detergent destruction is comparable to sludge reduction with ultrasonic and other methods. This provides an economical and efficient way to breakdown sludge in improving the wastewater treatment process.

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ACLOSEEXAMINATIONOFTHEDETERGENTDESTRUCTIONMETHODFORAEROBICTREATMENTOFWASTEWATERHIGHINDETERGENTWHDCONTENT

Strictly as per the compliance and regulations of:

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Abstract- Detergent wastewater has to be treated to prevent water pollution, especially for the reclamation of large quantity of laundry wastewater for reuse. A detergent destruction method removes detergent by using it to breakdown the activated sludge so as to prevent foaming when aerated in an SBR. Many research studies had reported methods and effects of increasing sludge reduction. A close examination of detergent destruction method to treat WHD has agreed well with the literature that activated sludge disintegration by consuming the detergent in wastewater has significantly reduced the activated sludge amount by mixing with and without aeration. The high rate of sludge reduction with detergent destruction is comparable to sludge reduction with ultrasonic and other methods. This provides an economical and efficient way to breakdown sludge in improving the wastewater treatment process.

I. INTRODUCTION

Detergent is used for cleaning purposes and is always present in wastewater. Detergent content in wastewater is not only a source of pollutant when discharged to the water course [1], its present can severely affect the normal functioning of conventional wastewater treatment because of severe foaming when aerated and can adversedly affect water reclamation by membrane technology [2]. Detergent removal from wastewater had been of concern in wastewater treatment in the past [3] and recently, in view of water scarcity, wastewater generated from laundry industry has become a potential source for water reclamation for reuse. Advanced oxidation process (AOP) using ozonation with combination of hydrogen peroxide was reported as an efficient way to treat detergent wastewater [4]. Combined biological and physicochemical treatment with UV/ozonation had also efficiently reduced the COD and completey removed the detergent from the laundry wastewater [5].

As reported in our earlier papers [6][7], a detergent destruction method with the use of biosorption and intimate mixing of activated sludge with WHD has enabled treatment of WHD with the efficient, cost effective and relatively simple conventional aerobic activated sludge process (ASP). This is particularly useful for wastewater generated from the detergent manufacturing and processing industry as even though the quantity of wastewater is small, detergent content is extremely high which poses problems for its aerobic treatment. The detergent destruction method engages the strategy of breaking down the detergent content prior to aeration so as to prevent detergent foaming. Incidentally the strategy is in fact a reversed idea of breaking down the activated sludge with the detergent. ie consuming the detergent to disintegrate the sludge. A good understanding of sludge breakdown is therefore important to reveal the details of the detergent destruction method.

Intended sludge breakdown is usually not a common practice of wastewater treatment processes and has not been emphasized in wastewater treatment technology. However there are many issues and advantages calling for the need to enhance sludge breakdown and hence it has been a rather popular topic for research studies. Basically, studies of sludge breakdown are for the purposes of improving aerobic and anaerobic digestion [8][9], to enhance biogas production [9], to facilitate a more efficient sludge dewatering process [10], to cope with excess or surplus sludge production in the ASP [11] and even to overcome the problem of nutrient deficiency in the anaerobic digestion process [14]. Interestinglly, sludge breakdown is now used as an approach to treat detergent wastewater aerobically. This takes advantage that sludge is disintegrated by the cleaning action of the detergent which in turn removes the detergent content to prevent foaming when the detergent water, especially, the WHD is aerated.

Many methods or strategies were used to enhance breakdown of the aerobic or anaerobic sludge, basically depending on the the purposes of sludge breakdown.

a) *Improving sludge digestion and bio-gas production by ultrasonic treatment*

Ultrasonic pretreatment before the anaerobic or aerobic digestion of the sludge were found to be able to release much of the extracellural polymeric substances (EPS) which are otherwise tightly bound on the surface of sludge floc or even be embedded in the pellets of the sludge floc. With the release of the EPS into the

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solution phase, prompt aerobic or anaerobic metabolic reactions can take place instantly and hence a more efficient sludge digestion process [8][9]. Enhance sludge solubilization generating more low molecular substances with alkaline-ultrasonic pretreatment has also resulted in increase in biogas production [9]. Sludge breakdown strategy is also useful for sludge digestion of industrial waste lacking in nutrient content. High sludge reduction by ultrasonic pretreatment has resulted in low sludge growth yield and hence a lower demand of nutrient for cell growth (14)

b) *To enhance efficiency of anaerobic digestion and dewater ability of secondary sludge*

Surplus activated sludge or the excess sludge generated in the aeration process is well known to be difficult for anaerobic digestion and has poor dewater ability.

Recent studies [10] on the rheological properties of the ultrasonicated waste activated sludge had revealed the significant release of soluble protein and a loosening and disruption of the internal structure of the WAS enabling the anaerobic metabolic reaction and favouring the dewatering process.

Similar investigation of sludge breakdown by pretreatment of the WAS with high ammonia concentration [11] had resulted in an increase in % volatile solids breakdown and hence an increase in dewatered sludge % solids content from 12.0% to 13.1%. Improved rate of anaerobic digestion is shown by an increase of 28.6% of biogas production

c) *Reducing the quantity of sludge generated*

Sludge breakdown was found to be able to significantly reduce the quantity of sludge for anaerobic digestion. This is particularly important for the large quantity of secondary sludge generated in the ASP. Investigation of sludge breakdown by induced acidic pretreatment and by mechanical means have both given high % of sludge reduction. The acidic pretreatment was achieved with inoculated special ammonia-oxidizing bacterium, '*Candidatus* Nitrosoglobus' [12] while the mechanical approach uses rotor stator type hydrodynamic cavitation reactor for sludge disintegration [13].

d) *Sludge breakdown by high detergent content in the wastewater which is also the objectives of this study.*

Treating WHD by aerobic ASP is successfully done by breaking down the detergent prior to the aeration [7] This takes advantage of the cleaning nature of the detergent. Biosorption and intimate mixing of the sludge with the detergent water or the WHD facilitate the sludge disintergration process. It was initially anticipating that the components, mainly the ESP from the disintegration of the sludge should be re-built into new sludge following the subsequent aeration process. Sugar supplement was used to replace some possible carbonaceous loss out of the sludge breaking down process, much the same as the endogenous respiration in the ASP.

This research study was carried out for a closer look of the sludge break down process.

II. METHOD AND MATERIAL

a) *A The Reactor System*

A sequencing batch reactor is used to treat WHD generated from the washing of used containers in a detergent processing factory. The WHD is fed into the SBR through an adsorption tank and the SBR has included a DESTRUCTION stage where detergent content is largely if not completely removed prior to the AERATE stage. Detergent removal is done by firstly having the detergent content largely adsorbed onto the activated sludge [6] and subjected to a prolonged and intimate mixing without aeration in the DESTRUCTION stage[7].

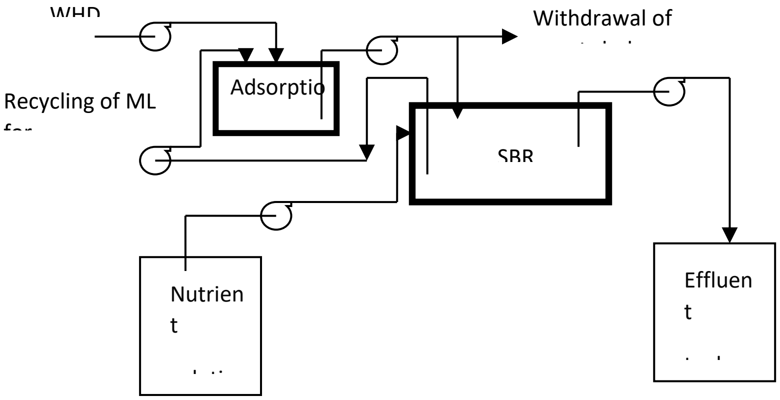

Figure 1: Reactor set-up for SBR with adsorption tank

The SBR has therefore the following stages per cycle.

FILL

DESTRUCTION

AERATE

SETTLE

DECANT

Schematic flow diagram for the SBR system is given in figure 1.

Mixed liquor is continuously recycled into the adsorption tank which is level control ie what flows in will overflow back to the aeration tank. The adsorption tank is not aerated throughout and is ONLY agitated when feeding with WHD. Hence there is deposition and cumulation of the activated sludge in the adsorption tank.

For a cycle of SBR operation, WHD is fed in the FILL stage. WHD enters the aeration tank through the adsorption tank which then has a very high activated sludge concentration through the thickening process before the FILL stage.

At the end of the FILL stage, the DESTRUCTION stage took place with agitation in both the adsorption tank and the aeration tank without aeration. With the continuous recycle of the mixed liquor, there is some degree of sludge deposition. The DESTRUCTION stage therefore prolongs the mixing of the detergent and the activated sludge prior to the AERATE stage facilitating destruction of the detergent.

With the AERATE, SETTLE and DECANT stages to complete the cycle of operation of the SBR, the WHD can then be treated with much reduction in COD and almost complete detergent removal as there is no foaming occurring in the AERATE stage. Detailed principle and operational procedures are published in our paper in 2019 [7]

b) *Materials*

The wastewater is produced from cleaning of the used containers returned from customers. Tap water is used and hence the wastewater is actually the washing water and is highly deficient in basic carbonaceous sources and the nutrients for cell growth. Depending on the level of Mixed Liquor Suspended Solids (MLSS), sugar or other simple food waste are added to the washings for biomass generation. Basic nutrients supplement and, in particulars, nitrogenous and phosphoric compounds are added. Urea and potassium hydrogen phosphates are used. List of nutrients and relative quantities are given in Table 1.

Most of the nutrients supplements, except the urea are being conserved and reused and needs only a small quantity of replenishment. Hence, only nitrogenous and the carbonaceous sources are frequently added.

c) *Plant operation*

The detergent factory generates 500L to 1000 L of washing water per day with Chemical Oxygen Demand (COD) ranging from 2000 to 4000 mg/L. The SBR is operated with a 12 hours cycles with the following stages:

FILL: 2 hours

DESTRUCTION: 10 hour

AERATE: 10 hours

SETTLE: 1.5 hours

DECANT: 0.5 hour

d) *Experimental procedures*

As this study is conducted to examine the detergent destruction process, ML samples were collected at end of cycle 1, the DESTRUCTION and AERATE stages of cycle2 for MLSS in mg/L determination. COD in mg/L were determined for supernatant of ML samples after 2 hours of sedimentation of the samples collected at the DESTRUCTION STAGE after 2 hours and 10 hours of operation in this stage and the effluent collected at DECANT stage at end of cycle 2.

The ML has a depth of 0.39 m at the end of cycle 1. After 1.5 hours of sedimentation, the SBR was decanted to a depth of 0.27 m.

The MLSS content is adjusted to the depth of the ML at the start of cycle 2 as given below:

Depth of ML in SBR at the start of cycle 2 = 0.27 m

Depth of ML in SBR at end of FEED cycle2 = 0.32 m

Hence MLSS in SBR:

Depth of ML x MLSS

= Depth of ML at start x adjusted MLSS (presented)

0.32 x MLSS of sample = 0.27 x MLSS adjusted (as presented in th Table2)

Therefore

MLSS presented = (0.32/0.27) x MLSS of sample

Volume of WHD fed to SBR

= (0.32-0.27)x1.5 m x3 m

= 0.05x1.5x3 =0.225 m^3

Table 1: Nutrients supplement for SBR

Urea: 0.6 kg/m^3
Di-Potassium hydrogen phosphate: 0.6 kg/m^3
Trace element solution: 1L/m^3

Composition of trace element Solution	Kg/m^3
MgSO4.7H2O	5
FeCl3.6H2O	7
Boric Acid	0.001
CuSO4.5H2O	0.001
(NH4)6Mo7O24.4H2O	0.550
NaCl	1
CaCl2.6H2O	2

III. RESULTS AND DISCUSSION

Table 2 and Figure 2 present the experimental data and their variation with time of operation. An increase in the MLSS from 4460 mg/L to 4807 mg/L two hours after the SBR was filled-up to 0.32m with the raw WHD while having the continuous mixing. An increase of the MLSS is possibly the adsorption and cumulation of the waste components from the WHD. This is also indicated with the sharp decrease in COD from 2032 mg/l of the raw WHD to 87 mg/L (adjusted to the same volume of raw WHD added) of the supernatant of ML after 2 hours of mixing. Biomass from the activated sludge is well acclimated to the raw detergent wastewater and is expected to rapidly adsorb the waste components from the WHD. While the COD remained very low in the range of 42- 87 mg/L, the MLSS has decreased by 6.7 % to 4485 mg/L after 10 hours in the DESTRUCTION stage with continuous mixing but without aeration. This can be explained by the solubilization of the activated sludge [8] due to the disintegration of the sludge with mixing in the present of detergent.

With ultrasonification pretreatment Guan et al [8] reported that after an aerobic digestion time of 10.5 d sludge reduction for TSS in aerobic digestion was 42.7%, compared with 20.9% without pretreatment (for control). Ultrasonic pretreatment has therefore achieved an additional reduction rate of 21.8%. In another study [11], anaerobic digestion of secondary sludge had an increase of 26.4% in sludge reduction.

In our study the MLSS has significantly reduced by 42.5 % from 4485 mg/L to 2579 mg/L after 10 hours of continuous aeration. The re-building of the sludge mass did not happen and for that reason, there is always the need of adding sugar supplement to maintain the necessary MLSS level . This shows that the sludge yield in the aerobic process must be very low. This agrees with the study that sludge reduction by external ultrasonic pretreatment of the activated sludge had a decrease of 15- 45% of sludge production yield. [14].

HyunsooKim et al [13] had reported 50%- 80% of sludge particles reduction when the sludge disintegration was done with rotor stator type hydrodynamic cavitation reactor. The sludge breakdown rate of 42.5% is therefore a remarkable effect in reducing excess sludge production as our study is only using simple and common method of mixing but with the detergent as an aid to the destruction process. It should be noted that treating WHD aerobically can achieve such prominent solids reduction comparable to the degree of destruction with sophisticated destruction methods like ultraonification, ammonia pretreatment etc. This shows that the detergent breakdown action had a very high potential in achieving sludge disintegration to improve aerobic and anaerobic digestion process. Table 3 gives a summary of sludge disintegration rate achieved by the method of detergent destruction method in treating WHD. Incidentally, the method has a double advantage of enabling aerobic treatment of WHD while preventing excessive activated sludge production even with sugar addition to facilitate the treatment method

IV. CONCLUSION

The detergent destruction method can efficiently treat WHD and other detergent wastewater by consuming the detergent to disintegrate the activated sludge to prevent severe foaming when aerated. The method has the advantage of preventing excessive generation of the activated sludge in the ASP even though sugar or other carbonaceous supplement is required to replenish the activated sludge for the detergent destruction action. This can be an economical and efficient way to achieve sludge disintegration for the improvement of wastewater treatment by the ASP. Use of detergent need to be appropriately control to prevent foaming occurring in the reactor or the digesters

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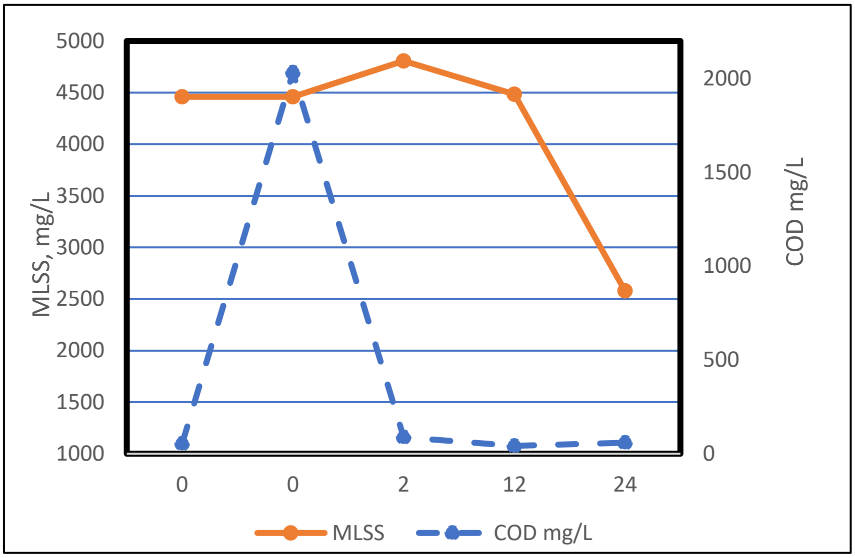
Table 2: Performance of SBR

Time Hrs	Reactor status	MLSS mg/L	COD mg/L
0	Cyce1 AERATION - 10 hrs (end)	4460	53
0	Cycle 2-FEED-raw WHD		2032
2	Cyce2-DESTRUCTION--2hrs	4807	87
12	Cycle2-DESTRUCTION--10hrs	4485	42
22	Cycle2-AERATION - 10 hrs	2579	58

Table 3: Nature of sludge integration

Time Hrs	Sludge disintegration	MLSS mg/L	% Reduction
2		4807	
12	Solubilization of sludge because of mixing with WHD MLSS 4807 to 4485	4485	6.7
22	Sludge disintegration =mixing and aerationLow possibly because of low sludge yield	2579	42.5



Abbreviation:

AOP	Advanced oxidation process
ASP	Activated sludge process
COD	Chemical oxygen demand
EPS	Extracellural polymeric substances
ML	Mixed Liquor
MLSS	Mixed Liquor suspended solids
SBR	Sequencing Batch Reactor
WAS	Waste Activated Sludge
WHD content	Wastewater High in Detergent

Figure 2: Performance of SBR

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Assessment of Soil Fertility Status under Different Farmers' Soil Management Practices in Karu Local Government Area of Nasarawa State Nigeria

By Duze M. K. Lawal, Dalhatu U. Sangari & Samaila K. Ishaya

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Abstract- The study assessed fertility status under different farmers' soil management practices. A total of18 soil samples were collected at an interval of 50 meters, 3 samples from farmers' soil management practices considered under this studies such as (Compost, Mix-farming, Tillage, Zero-tillage, Mix-cropping, and Mono-cropping). 1 sample was collected at 50 meters away from the farm sites to serve as control for the studies. Standard laboratory methods were used to determine the concentrations of the variables covered by this study. The study reveals that pH ranges between 5.36 in zero-tilled soils to 6.12 in tilled soils, electrical conductive was generally low in the study area ranging between 0.99uS/cm to 2.43uS/cm. Nitrogen was generally low in all the sampled soil with tilled soil having the least concentration of 0.31meq/kg and compost soil having the highest concentration of 0.49meq/kg. Tilled soils recorded the lowest concentration of organic matter 2.10% and compost soils with a concentration of 2.71%. Since the soils have been found to be deficient in some of the nutrients necessary for plants growth, there is the need for addition of organic or chemical fertilizers. The addition into the soil of about half a ton of NPK per hectare will greatly enrich the soil with nutrients which are a necessity for plants growth.

Keywords: fertility, farmers', soil, management.

GJSFR-H Classification: DDC Code: 631.42 LCC Code: S633

Strictly as per the compliance and regulations of:

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I. INTRODUCTION

Soil management concerns all operations, practices and treatments used to protect soil and enhance its performance (Wikipedia). They are practices that affect soil quality which includes controlling traffic on soil surface, the use of cover crop, crop rotation, nutrient management and conservation tillage. The goal of soil management is to protect soil and enhance its performance, to farm profitably and preserve environmental quality for decades to come. This implies, the management of agricultural soils would maintain the soils productivity in an ecologically, economically and culturally sustainable system of soil management. Bationo, Traore, Kimetu, Bagayoko, Kihara, Bado, Lompo, Tabo, and Koala. (2004). According to Rahji and Omotesho, (2006), the main issue in the Nigerian agriculture is that of low productivity. The greatest threat to sustaining agricultural productivity in the Nigerian farming communities is the declining productivity of soil caused by the loss of soil fertility through the erosion of top-soil brought about by inappropriate land use practices and the loss of soil water content, soil structure and porosity due to persistent laterisation of the top soil as a result of continuous exposure to sun by man and animals (Aromolaran,1998).

Soil is the most important resource required for agricultural production (Khanif, 2010). The most important constraint limiting crop yield in developing nations, and especially among resource poor farmers, is declining soil fertility (Khosro and Yousef, 2012). Soil fertility is declining in many parts of Sub-Saharan Africa (Stoorvogel, Smaling, and Janssen., 1993). Soil fertility is declining throughout the country primarily due to reduction in the length of fallow periods, lower levels of fertilizer application, complete removal of crop residues from fields, use of dung as a household fuel, and lack of adequate soil conservation practices (Eyasu, 2002). As a result, there is a growing concern that fertility depletion will seriously limit food security and sustainable agricultural production in Ethiopia (Shiferaw and Holden 2000; Bewket and Sterk, 2002).

One of the most severe threats to the sustainability of agricultural crops production in Nigeria is declining productivity as a result of the loss of soil fertility. Soils in Nigeria suffer deficiency common to the soils in the tropic such as a low percentage organic matter and nitrogen, shallow depth and high acidity which predispose about 63% of agricultural soils in Nigeria to low productivity (Lekwa and Whiteside, 1996). There are different ways in which farmers till the lands. Some of the methods include selective and total felling of trees, controlled and uncontrolled bush burning, conventional and manual tillage, different planting and harvesting methods and judicious and injudicious application of fertilizers (FAO, 2013). The stated methods and hosts of others not mentioned either adds nutrients to the soil or cause soil degradation. The problem of land scarcity for food crop production is aggravated by rapid urbanization, conversion to nonagricultural uses, and severe soil degradation (Birte

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Robert, David, and Karl, 2008). Overuse of soils causes acidification, salinization or other chemical soil contamination. Soil Scientists need to adapt a positive approach to natural resources management. The soils need to be preserved to avert future hunger strike. Crop production depends largely on soil and is affected greatly by the quality of that soil. Soil quality also plays a role in the environmental effects of crop production. Soil management involves actions by land managers that affect soil quality and productivity and alter soils effects on environmental quality. Examples of these actions include land use or cropping pattern, type and extent of tillage, amount of cover or residue left on the soil and use of conservation buffers and structures. Soil as a plant growing medium is the key resource in crop production. Soil supports all the processes that plant needs to grow. Oladipo, Bolarin, Daudu, Kayode, and Awoyele, (2017).

Despite all these, recent evidence has shown that farmers have not been eager to adopt or invest in soil management practices. (FOA, 2011) observed that some of the farming system practices aimed at tackling soil quality decline and degradation has wide spread acknowledgement with low usage. FOA, further revealed that most of the projects on soil management were carried out on research farms and only a few on-farms with the participation of farmers. Therefore, there is a need to identify adopted soil management practices and assess them to address long term sustainability of Nigeria's soil resources which should be put in place by stakeholders and required to sustain yield increases in the major crop production systems in Nigeria and to increase the efficiency of farmers in the adoption of researched technologies. With the foregoing, this study assesses soil fertility status under different farmers' soil management practices in Karu Local Government Area of Nasarawa State.

II. Materials and Methods

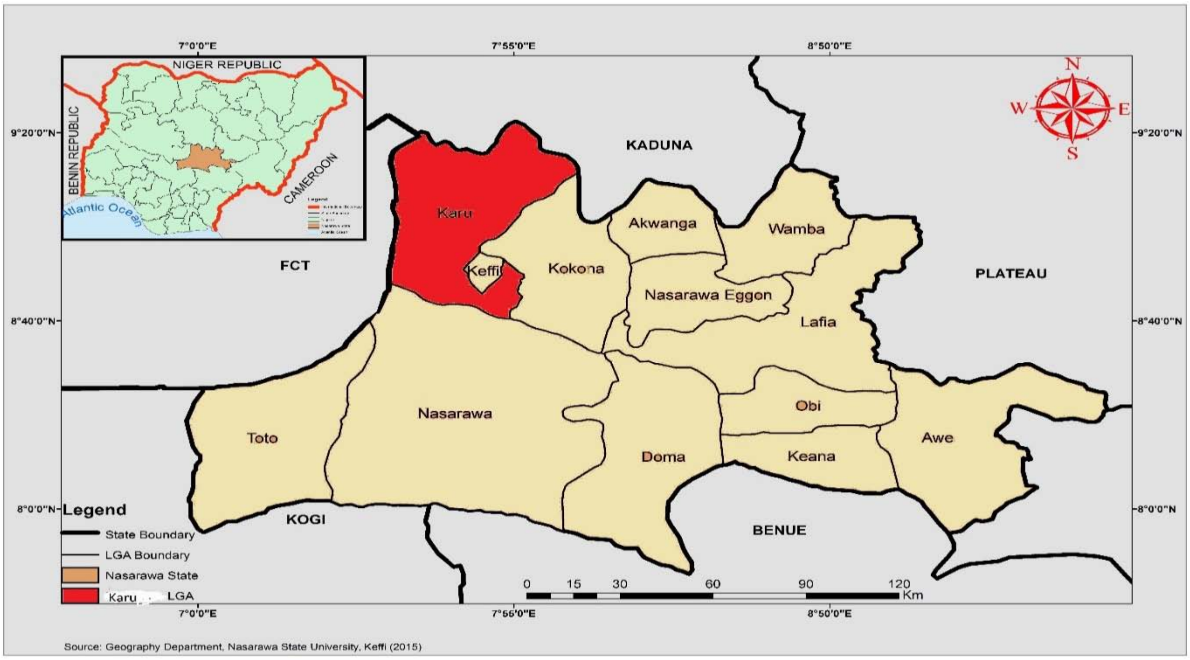
Karu Local Government Area is located within latitude 8° 59' 46''N and longitude 7° 34' 32'' Elatitude $9^0$25' N and $8^0$00'E. Karu is one of the Local Government areas of Nasarawa State Nigeria. It shares its western boundary with the Federal Capital Territory of Nigeria, its eastern boundary with Keffi Local Government of Nasarawa State, its southern boundary with Nasarawa Local Government Area and its northern boundary with Kaduna State. It has approximately area of 2,640km^2. Karu L.G.A has its headquarters in new karu town. The L.G.A is made up of two development area which are Panda and Karshi Development Area and various settlements.

Karu Local Government Area of Nasarawa state like other parts of Northern Nigeria has climate that correlates with that of savanna belt. It is under the influence of inter-tropical convergence zone (ITCZ). The area has a distinct wet and dry season. The wet season starts from about the beginning of May and ends in October and the dry season is experienced between November and April. Annual rainfall ranges from about 1100mm to about 1200mm (Bimbol, 2007). About 90% of the rain falls between May and September. The temperature is generally high during the day particularly between the months of March and April. The mean monthly temperature is in the range of 20^{0}C to 34^{0}C with the hottest month being March and April and the coolest month being December and January (Bimbol, 2007).

The vegetation on the hilly parts of the area are composed mainly of grasses and isolated trees. Trees of economic value including locust beans (Parkiabiglobosa), Shea butter (Vitellariaparadoxa), Neem (Azadirachtaindica), Mango (Mangiferaindica), Citrus (Citrus X sinensis) and Banana (Musa acuminaia), are scattered across the area, particularly in the lowland areas and the southern part of the study area. (Aboki, Mailafiya and Osaba, 2007).

The geology of the study area is made up basement complex rocks cover about 70% of the total superficial area of the state while the remaining 30% is made up of sedimentary rocks of the middle Benue trough. The younger granites intrude the basement complex and therefore do not occupy any separate landmass of their own. Of the basement complex, migmatite –geisses along with the older granites account for about 70% while rocks of the schistose lithology and other metasedimentary series amount for the remaining 30% (schist, quartzite, marble, ironstone). (Obaje, Lar, Nzegbuna, Moumouni, Chaanda, and Goki, 2007).

The area lies between 300-100 meters above the sea level except the hilly areas of Kajari and Gitata whose elevation reached 2154 meters in Kajari and 2760 meters in Gitata respectively. The Uke River is another major river in the state that flows through the northwestern corner of Karu hills to the southwest Kugwaru forest. The river takes it source from the North-Central Highlands and flows through towns like Panda and Nasarawa Benue east of Umaish. Its major tributaries are rivers Ado, Obi and Antau (Samaila and Bimbol, 2007).



Source: Geography Department, Nasarawa State University, Keffi (2015)

Figure 1: Map of Nasarawa state showing Karu L.G.A

Soil samples were collected where the following farmers' soil management are taking place (Compost, Mix farming, Tillage, Zero Tillage, Mix cropping and Mono cropping). The choice of the farmers' soil management fields was based on the duration of not less than three years at which the soil management has been in practiced on such a field. Three soil samples were taken at 50 meters interval on the soil management fields covered by this study for each season. A total of 18 soil samples were collected using a soil auger to burrow a hole thirty centimeters deep into the soil and 1 control sample from 50meters away from the farming sites. The soil was thoroughly mixed and a 1kg representative sample was collected in polythene bags and for taken for laboratory analysis. Properties measured of soils included pH and electrical conductivity by Jenway portable meter, sodium, calcium and magnesium by Ammonium acetate leaching method, potassium and organic matter by Atomic absorption spectrophotometer, organic matter by dichromate wet oxidation, available phosphates using Olsen sodium bicarbonate method, Cation Exchange Capacity by Ammonium acetate method, nitrogen % by Macro Kjedhal wet oxidation method and particle size analysis by Hydrometer method. The results of laboratory analysis for both the soils were summarized in table 1.

III. Result and Discussion

The result presented in table 1 shows that pH in the soil has a minimum concentration of 5.36 in zero-tilled soils and a maximum concentration of 6.35 in mix-farming soils. The control point has a value of 6.34, indicating a moderately acid to slightly acid-base reactions. This shows that pH level under tillage management practices soil may affect the yield of crops in the study area. This could be attributed to low organic matter, high soluble content, amount of bases and the acidic nature of the soil is as a result of the parent material from which the soils were derived and high rate of leaching of nutrient down the profile, which makes the soil soluble that is it, can easily react with chemical properties in the soil. (Igwe,2005). Collaborate with the finding. That the acidic nature of the soil may be due to the acidic nature of the parent material from which the soils were derived and high rate of leaching of the nutrient down the profile.

Electrical conductivity has a minimum concentration of 0.99 uS/cm^3 in tilled soils and a maximum concentration of 2.67uS/cm^3, the control point has a concentration of 4.12 uS/cm^3. *This* uniformity may not be unconnected with the similarities in soil type, geology and the agricultural management found in the study area. This low Electrical conductivity values indicate that the area is not prone to salinity threats and the soils will support many crops. The slightly acid nature of the soil will enhance the availability of nutrients and as shown above may further facilitate the solubilisation of sodium ions which are the primary agents of salinization and alkalinisation especially in irrigated soils.

Organic matter has positive effects on the soil. It generally increases soil nutrient and water holding capacity, increases aeration, decreases bulk density, and leads to more stable aggregates. The result shows that the value of organic matter in the study area has a minimum concentration of 2.10%in tilled soils, a maximum concentration of 2.71%, the control point has a concentration of 3.10% The organic matter in the study area can be categorise as low, this can attributed to erosion, leaching and due to the nature of the soil texture in the study area. Low organic matter reduces infiltration, CEC and buffering capacity of the soil. In agreement with the finding Tilahun, (2015) observed that leaching and erosion has eroded organic matter and organic carbon down the soil profile.

Table 1: Mean physical and chemical properties of soils on different farmers' soil management practices for wet season

Soil Properties	Unit	Compost	Mix-farming	Tillage	Zero-Tillage	Mix-cropping	Mono-cropping control
pH		5.40	5.71	6.12	5.36	6.35	6.11	6.34
ECe	uS/cm^3	2.22	2.43	0.99	2.15	2.67	1.99	4.12
O.M	%	2.62	2.71	2.10	2.23	2.34	2.35	3.10
N	meq/kg	0.49	0.43	0.31	0.45	0.33	0.39	0.49
P	meq/kg	4.33	3.65	3.34	3.56	3.62	3.90	4.63
K	meq/kg	0.68	0.65	0.45	0.65	0.60	0.62	0.65
Ca	meq/kg	3.41	3.83	2.95	3.28	3.71	3.83	5.32
Mg	meq/kg	3.32	3.91	2.84	3.81	3.87	3.71	4.31
Na	meq/kg	0.49	0.45	0.31	0.39	0.40	0.42	0.95
CEC	Cmol/kg	6.98	7.10	5.52	7.05	5.59	6.45	7.34
Texture							
Sand	%	75.8	82.8	82.8	75.8	80.8	75.8	75
Slit	%	5.4	4.4	4.4	5.4	4.4	5.4	5.8
Clay	%	18.8	12.8	12.8	18.8	13.8	15.8	19.2

Source: Field Survey 2019

Total Nitrogen in the sampled soil, has minimum concentration of 0.31meq/kg in tilled soils, a maximum concentration of 0.49meq/kg in compost soils, with a control point concentration of 0.49meq/kg.Nitrogen is the most critical element obtained by plants from the soil and is a bottleneck in plant growth. The low value of Total Nitrogen can be attributed to the low level of Organic matter, organic carbon and continuously and intensively cultivated soil in the study area. Tilahun, *(2005)*collaborated with the finding. He observed that the N content is lower in continuously and intensively cultivated and high sodic soils of semi-arid and arid regions due to low Organic Matter content.

Available P in the study area, has a minimum concentration of 3.34meq/kg in tilled soils, a maximum concentration of 4.33meq/kg in compost soils, with a control point concentration of 4.63meq/kg. The low concentration of available phosphorus in the study area can be attributed to the coarse nature of the soil, leaching and erosion in the study area. Available P is generally low in the all the sampled soils considered under this study. Low P can be attributed to textural class, and Organic Matter. Phosphorus is known as the master key to crop growth because lack of available P in the soils limits the growth of both cultivated and uncultivated plants. (Brady and Weil, 2002) collaborated the findings that erosion tends to transport clay and organic matter fractions of the soil, which are relatively rich in P fractions. The low content of available P of soils in the study area is in agreement with the study of (Igwe 2005; Mustapha and Udom 2005 and Shehu, Jibrin and Samndi, 2015) that available phosphorus under most soils of Nigeria decline by impacts of fixation, crop harvest and erosion.

Potassium has a minimum concentration of 0.45meq/kg in tilled soils, a maximum concentration of 0.68meq/kg in compost soils, with a control point value of 0.65meq/kg. The Low value of potassium in the study area can be attributed to the acidic nature of the soils in the study area, leaching and intensive cultivation. Potassium is essential for the general vigor of the plants, encourages the development of a strong root system and increases resistance to certain diseases. Mesfin (1996) described low presence of K under acidic soils while Alemayehu, (1990) observed low K under intensive cultivated soils.

Calcium in the study area has a minimum concentration of 2.95meq/kg in tilled soils, a maximum concentration of 3.83meq/kg in mix-farming and mono-cropping soils, with a control point value of 5.32meq/kg. Kowal and Kassam (1978), gave a range of 0.5-4.0meg/kg as the range of calcium levels for savannah soils of West Africa.Luo, Lindsey, and Xue,(2004) recorded 6.5 mg/kg for Horotiu soils in China. The high calcium observed for the soil implies that the ion may not precipitate to a level in the soil to impact negatively on internal drainage and affect the performance of plants in their development. In the case of Magnesium, it has a minimum concentration of 2.84meq/kg in tilled soils, a maximum concentration of 3.91meq/kg in mix-farming soils, with a control point value of 4.31meq/kg. The low level of Magnesium can be attributed to the low value of organic matter, solubility of the soil in the study area. The presence of adequate amounts of calcium and magnesium in the control soil is very important in order to obtain satisfactory crop yield.

Sodium values covered by the study has a minimum concentration of 0.31meq/kg in tilled soils, a maximum concentration of 0.49meq/kg in compost soils, with a control point value of 0.95meq/kg. Low Na can be attributed to the sandy nature of the soil and low pH in the study area. Low Na affects the internal drainage of soil, water logging, plant developmental process, aeration, germination of plant and important macro nutrient requirement in the soil, which will make the soil not to precipitated Ca, Mg and K. Egboko, (2008) observed the same trend in the distribution of sodium at gully sites, on gully erosion in Agulu-Nanka, Anambra State Nigeria.

Cation Exchange Capacity in the study area, has a minimum concentration of 5.52Cmol/kg in tilled soils, a maximum concentration of 7.10Cmol/kg in mix-farming soils, with a control point value of 7.34Cmol/kg. CEC is a basic single index of potential fertility, is the capacity of the soil to hold and exchange cations. It affects the soil capacity to supply nutrients cations for plant growth, it is generally low in all the soils sampled. The relatively low value of CEC in the study area can be attributed to low amount of clay and organic matter in the study area. Curtis and Courson, (1981), collaborated the findings by observing that CEC of soil is strongly affected by the amount of clay and organic matter present in the soil. Both clay and colloidal organic matter are negatively charged and therefore can acts as anions.

IV. CONCLUSION

Current information on farmers' soil management practices is needed to develop appropriate integrated nutrient management packages for sustainable crop production within the area. The six soil management practices in general maintain a comparative low soil quality than the control soil, the control soil has high level of organic content and the cultivated soil has a textural class which encourage soil erosion and leaching of major soil nutrients. This once again underscore the important role organic matter plays in maintaining soil fertility in tropical soils low activity clays where the study area is situated.

In order to raise the productivity level of the land to optimum performance for crop yield, the management techniques should enhance the nutrient and moisture holding capacity of the soil. Such techniques should include; continuous application of organic fertilizers/materials to the soil, improved efficiency of use of mineral fertilizers and use of low levels of chemical inputs, putting up appropriate drainage facilities in place to take care of the poorly drained area of the land while provision of irrigation facilities would make dry season farming possible.

Since the soils have been found to be deficient in some of the nutrients necessary for plants growth, there is the need for addition of organic or chemical fertilizers. The addition into the soil of about half a ton of NPK per hectare will greatly enrich the soil with nutrients which are a necessity for plants growth.

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Vulnerability Analysis of Ground Water in and Around MSW Disposal Site Mathuradaspura, Jaipur using Multivariate Statistical Techniques

By Aruna Saini & Priya Kanwar

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Strictly as per the compliance and regulations of:

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Abstract- Dumping of municipal solid waste in an open dumping site is a big threat to the environment affecting all the natural resources. This threat reaches to groundwater through leachate which even though takes a lot of time to percolate, through the soil profile and rocks beneath, and reach the water table but once contaminated it is very difficult to clean the groundwater. This has given a motto to attempt a study on the groundwater quality analysis of the area in and around Mathuradaspura dumping site which is receiving around 500 to 600 tonnes of solid waste daily from Jaipur Municipal Corporation. The study was taken up during 2020 and about 26 water samples were collected from the dump site and its vicinity. These samples were analysed for basic quality parameters and heavy metals. The variability of water quality in the area was figured out by subjecting the parameters to multivariate statistical analysis including correlation analysis (CA), Principal component analysis (PCA) and Hierarchical Cluster Analysis (HCA). Correlation analysis and PCA helped in establishing the inter-relationship of the quality parameters and major parameters responsible for deciding the groundwater quality of the area and their possible causes, respectively. The PCA confirmed the results of CA by classifying the parameters into four principal components that area responsible for total 76% variance of hydrochemical data of the study area. The application of HCA has resulted into the formation of three clusters each of Q and R modes depending on dominant chemical composition which describes the spatial distribution of samples and the possible causes influencing the groundwater quality of the study area.

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I. INTRODUCTION

Rapid urbanization, growing population and vast industrial development has affected all the natural resources that have resulted in stern environmental challenges and serious concern for the controlling and governing agencies.[1,2,3,4] These developmental processes and its related requirements are producing waste at even faster rates. The waste generated in these areas needs disposal sites which usually are open areas outside the municipal limits [5]. These sites if not designated scientifically poses threat to the air, soil, surface water and very badly to the groundwater if leachate from it percolates down [6]. The vulnerability of ground water, around an open dumping site, for getting polluted, increases many folds especially when it is an unscientific and unplanned site. [7,8]. Jaipur City is also facing similar problem of huge solid waste and also the solid waste generated in the Municipal area is being dumped in at open dump sites of Mathuradaspura and Sewapura [9]. The present study aimed at Mathuradaspura dumping site with an objective of to assess the degree of impact of the municipal solid waste on the groundwater of the area in the 2020. The groundwater samples as well as the identified chemical parameters were subjected to various statistical analysis to understand the inter-relationship among water samples as well as chemical parameters and the extent of contamination of groundwater of the area.

Multivariate statistical methods provide information from which cause-and-effect relationships can be established [10]. These methods are frequently employed to characterize the quality of groundwater as they effectively represent the data concerning groundwater pollutants and geochemistry [11]. The inter-relationship between any two quality parameters assessed through Pearson correlation analysis which is a bivariate method. A high correlation coefficient value (i.e., -1 or 1) predicts a good relation between two variables and correlation coefficient value around zero (o) predicts no relationship between them at a significant level of (p) of < 0.05[12]. Parameters showing $r > 0.7$ are considered to be strongly correlated whereas $r > 0.5\text{-}0.7$ shows moderate correlation and parameters showing $r < 0.5$ shows weak or no correlation [13,14]. Cluster and factor analysis are proficient ways of presenting the complex relationship among many samples [15,16]. To assess the chemical quality and establish the correlations between the groundwater samples collected and the chemical parameters that were analysed, well established independent and quantifiable approaches of Principal Component Analysis (PCA) and Hierarchical Cluster Analysis (HCA) were applied. The PCA is a very powerful tool used to reduce the dimensionality of large data set of interrelated variables into few factors called the principal components which can be interpreted to reveal fundamental data structure [17,18]. The hierarchical clustering is one of the most widely practical in Earth sciences [19], and often used in the categorization of

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hydrogeochemical data [20,21,22,23].The result of clustering is a Dendrogram representing the nested grouping of patterns and resemblance levels at which groupings change.

II. Study Area

Jaipur, capital of India's largest state Rajasthan, with a crown of "World Heritage City" also has a pride of one of the oldest planned cities of India. It was founded in 1728 A.D. by Maharaja Jai Singh was in an area of 6 sq.km has now expanded to an area of 532.7 sq.km. It has experienced vast expansion with exponential increase in population, industrial growth and other activities leading to urbanization. As per census 2011, the city has a population of more than 30 lakhs and many industrial areas have come up along with other amenities as a necessity of growing population. This noteworthy development has resulted in a major challenge of disposing the huge municipal waste. This municipal solid waste (MSW) of Jaipur City is being dumped at two sites viz. Mathuradaspura and Sewapura, located at a distance of 17 km in east and 20 km in north of the city. Another dumping site located in the north-east of Mathuradaspura was near village Langadiyawas where waste was being dumped till 2017 is now a passive site and is no longer in use [24]. This study was taken up to assess the impact of the waste being dumped at Mathuradaspura dumping site and to assess if the passive site is still contributing to the chemical quality of the area [25].

Mathuradaspura is a village located in Jamwa Ramgarh Block of Jaipur District located between East longitude 75°51'00" to 76°01'50" and North latitude 26°54'00" to 27 01'00" at distance of 19 km from Jaipur in the eastern direction (Figure 1). It has total geographical area of 3.65 sq.km and surface elevation of 370 m amsl. The total population of about 1000 persons and area is characterized mainly by agricultural crop land. It is drained by Dhund River which is ephemeral and flows from north to south.

The Mathuradaspura dumping site covers an area of about 0.44 sq.km located within the alluvial plain bounded by hillock on the eastern by forests on its western edge. The surface is gently sloping towards south-west.

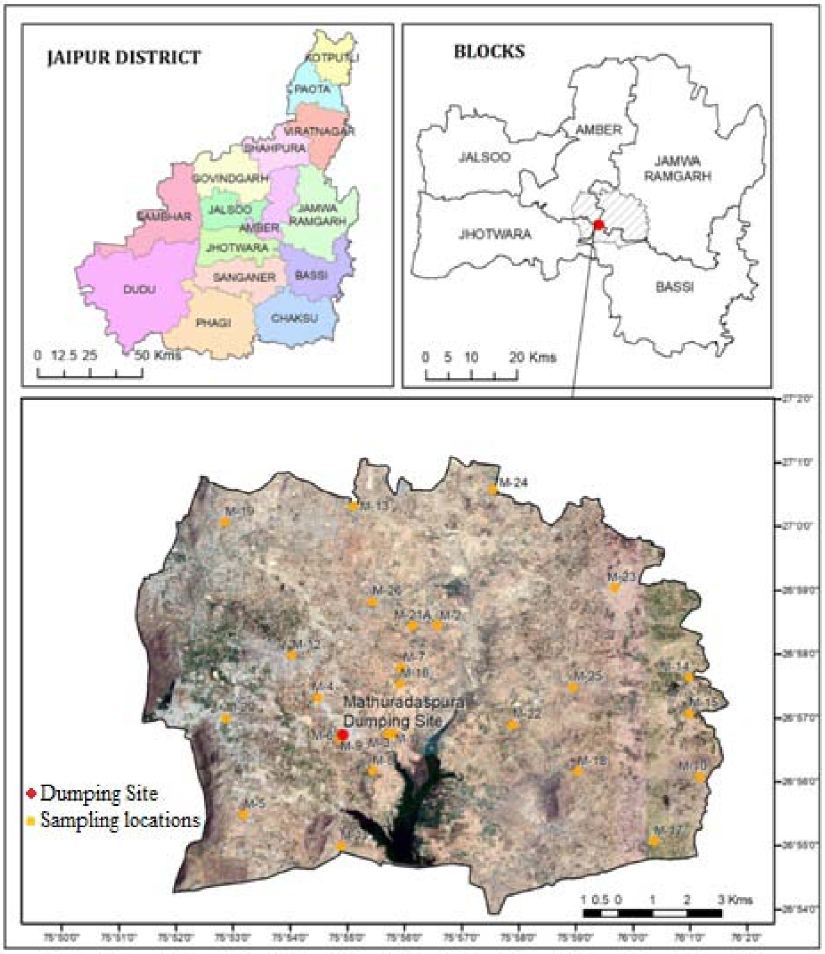

Figure 1: Study Area Map

Almost 500 to 600 tonnes of waste are disposed at this open dumping site without any segregation or treatment as shown in figure 2. This un-segregated waste disposal at an open site imposes serious environmental issues. Liquid from wet waste and rainwater percolates through the waste and gets accumulated at the bottom of landfills from where it reaches the groundwater.

The aquifer in the study areas is mainly occupied by unconsolidated Quaternary alluvium where groundwater occurs under un-confined to semi-confined conditions in alluvial aquifers, whereas in hard rock aquifers groundwater in general, occurs under un-confined conditions. In hard rock aquifers, groundwater occurrence is controlled by thickness of weathered zone, size, continuity and interconnectivity of fractured zones and other secondary porosities. In general, the yield of wells tapping alluvial aquifers varies from 1.9 to 9.7 lps depending on the thickness of saturated granular zones and the yield of the wells tapping hard rock aquifers in ranges from 0.83 to 5.6 lps.

Figure 2: Mathuradaspura Dumping site

III. Sampling and Laboratory Analysis

To analyze the impact of uncontrolled and unscientifically dumped municipal solid waste on the groundwater quality, 26groundwater samples were collected from hand pumps and dug wells of the study area in May 2020.The samples were collected in 1L polyethylene bottles without preservation. The important in situ parameters such as temperature, electrical conductivity (EC) and pH were analyzed immediately at sampling site by using standard portable pH/EC meter (Hanna). The collected water samples were safely transferred to the National Accreditation Board for Testing and Calibration Laboratories (NABL) accredited laboratory of Central Groundwater Board, Western Region, Jaipur for analysis of various hydrochemical parameters by following the procedure specified in APHA [26]. Total Hardness (TH) and Calcium (Ca^{2+}) as $CaCO_3$ was analysed using titrimetric method with Ethylene-diamine-tetra-acetic acid (EDTA, N/50) and Mg^{2+} was estimated by calculation. Carbonate (CO_3^{2-}) and Bicarbonate (HCO_3^-) were measured by acid titration method and Chloride (Cl^-) concentration was measured by $AgNO_3$ titration method. The F^- concentration in groundwater samples analyzed by an Ion selective electrode (Model 781, Metrohm).UV-Visible spectrophotometer (Model 3200, Lab India) was used for determination of Sulphate (SO_4^{2-}) and Nitrate (NO_3^-) ions. Sodium (Na^+) and potassium (K^+) were analyzed using Flame photometer (Model-128, Systronic). Five most common heavy metals viz. Copper (Cu), Zinc (Zn), Nickel (Ni), Lead (Pb) and Iron (Fe) were analyzed by Atomic absorption spectrophotometer (PG Instruments). The ionic balance error for measured ions was within ±5%. The analytical results of physico-chemical parameters of groundwater were compared with the BIS [27] standard guideline values recommended for drinking water. The analyzed data was taken to the ARC-GIS V10.3.1environment for preparation of maps to analyze the spatial distribution and variation of various chemical parameters in the groundwater of the area. The degree of inter relationship, between the hydrochemical parameters, was identified by Pearson’ correlation coefficient. The Pearson’s correlation matrix was generated using SPSS 25.0 for windows. To characterize the groundwater quality in and around the dumping sites and to simplify and organize the large dataset for better understanding the interrelation of chemical variables the data was subjected to various chemometric techniques which includes statistical tools like PCA and HCA.

IV. Results and Discussions

The solid waste placed in landfills or open dumps are subjected to either groundwater underflow or infiltration from precipitation. During rainfall, the dumped solid wastes receive water and the by-products of its decomposition move into the water through infiltration. Once disposed off in landfill, solid waste undergoes various physico-chemical and biological changes. Therefore, the groundwater in the areas near Mathuradaspura dumping site, are more vulnerable to pollution. The groundwater in and around this dumping site is mainly used for domestic, agriculture and formation of bricks.

V. Groundwater Chemistry

pH is a significant operational water quality parameter. There is an important observation, that pH values in almost all the water samples collected from the proximity of dumping yard is comparatively higher than the farther locations. It varies between 7.36 and 8.46 shows alkaline nature of groundwater of the study area. The highest pH value 8.46 was recorded at M-22 (Dangawara Khurd) in study area. The EC values of the groundwater samples ranges from 700 μS/cm in sample number M-23 to 5670 μS/cm in M-2 and the average value was 2299 μS/cm. Most of the samples had higher EC values > 1000 μS/cm and samples collected from tube-wells of the study area had higher EC values indicating the presence of more soluble salts. The TDS of groundwater ranges from 455 mg/l to 3686 mg/l with an average value of 1495 mg/l. Similar to pH and EC, 23% sampling locations in proximity of dumping sites viz. M-20, M-21, M-8, M-4, M-12 & M-2 have exceeded the permissible limit of 2000 mg/l TDS as specified by BIS for drinking water and is non-potable.

The total hardness, which results due to the presence of alkaline earths such as calcium and magnesium, varied from 50 mg/l to 1050 mg/l with an average of 308 mg/l in the study area. According to Swayer and Mc Carthy 1967 [28] classification about 65% of the groundwater samples fall under hard to very hard category. About 53% of the groundwater samples exceeds the acceptable limit of TH as prescribed by BIS viz. 200 mg/l and 11.6% of the groundwater samples exceeds the permissible limit of 600 mg/l. The concentrations of calcium(Ca^{2+}) in the groundwater samples ranges from 12 to 240 mg/l (average 51 mg/l) and magnesium (Mg^{2+}) values varies from 2.0 to 119 mg/l (average 44 mg/l). In few sampling locations lying in the vicinity of dumping yard viz. M-8, M-12 & M-20, Ca^{2+} and Mg^{2+} both exceeds the permissible limits which may be due to leachate infiltration or agricultural activities. Similarly, sodium concentration was found more than 500 mg/l viz. M-3 (590 mg/l), M-21 (690 mg/l), M-8 (700 mg/l), M-12 (770 mg/l) & M-4 (830 mg/l) in the areas lying in the close vicinity of dumping site owes to addition of Na^{+} from MSW and weathering of other silicate minerals. High concentration of sodium in drinking water may pose a health risk to persons suffering from cardiac attack, renal dysfunction and epidemics. The concentration of potassium range between 1.0 to 14.0 mg/l. Potassium is found to occur in very low concentrations in the groundwater of the study area.

Carbonate ion is not present in groundwater of study area, whereas bicarbonate ion is the most dominant anion. It varies from 281 mg/l to 988 mg/l. High chloride concentration in water is a direct indicator of water pollution in an aquifer. Chloride concentration more than 250 mg/l is generally objectionable for a municipal use. High Cl^{-} content in groundwater is likely to originate from pollution sources such as domestic effluents and fertilizers and is injurious to persons suffering from heart diseases or renal issues. The highest concentration of Cl^{-} was reported at M-12 (752 mg/l) and M-2 (1383 mg/l) which lies in close proximity to dumping site. 43% samples have exceeded the acceptable limits of Cl^{-} (>250 mg/l). Sulphate has various sources like animal sewage, by-products of industrial waste, fertilizers and natural deposits and by which it can mix with water and deteriorate its quality for various uses. Water samples from four observation wells (M-4, M-8, M-20 & M-25) exceeded the acceptable limit of 200 mg/l and two locations (M-2 & M-12) exceeded the permissible limit of 400 mg/l which may be due to drainage from farm and sewage effluents. Nitrate concentration greater than 45 mg/l is undesirable in domestic water supplies because of the potential toxic effects on young infants. The nitrate concentration ranges from 1.0 mg/l to 300 mg/l. The highest concentration of nitrate was found at the five locations (M-25, M-9, M-19, M-12 & M-20). These locations are located away from the landfill in the northeast direction. Fluoride concentration varies from 0.52 mg/l to 4.23 mg/l and 27% of the groundwater samples have fluoride concentration beyond the permissible limit of 1.5 mg/l. The median value of all the quality parameters is shown in figure 3.

Results of detailed physico-chemical analysis with statistical comparison of the groundwater samples is summarized in Table: 1

Table 1: Descriptive statistics of measured parameters compared to BIS, 10,500 for drinking purpose

Parameter	Units	Minimum	Maximum	Mean	Standard deviation	BIS,10500 guideline		% of samples exceeding guide line	
						Accept-able Limit	Permissible Limit	Acceptable	Permissible
pH		7.36	8.46	8.02	0.26	6.5-8.5	NR	--	--
EC	µS/cm	700	5670	2299	1287.49	-	-	--	--
TDS	mg/l	455	3686	1495	836.87	500	2000	69.2	23.1
TH	mg/l	50	1050	308	200.31	200	600	57.7	11.6
Na^+	mg/l	23	970	399	248.13	--	--	--	--
K^+	mg/l	1.0	14	3.4	2.71	--	--	--	--
Ca^{2+}	mg/l	12	240	51	49.93	75	200	15.4	3.8
Mg^{2+}	mg/l	2.0	119	44	29.40	30	100	61.5	7.7
HCO_3^-	mg/l	281	988	665	200.31	--	--	--	--
Cl^-	mg/l	7.0	1383	325	317.57	250	1000	42.3	3.8
SO_4^{2}	mg/l	2.0	458	125	138.7	200	400	15.4	7.7
NO_3^-	mg/l	0.0	300	48	71.52	45	NR	19.2	--
F^-	mg/l	0.52	4.23	1.34	0.73	1.0	1.5	42.3	26.9
Fe	mg/l	0.0	5.4	0.683	1.39	1.0	NR	23	--
Ni	mg/l	0.0	0.04	0.004	0.01	0.02	NR	11.5	--
Zn	mg/l	0.0	3.5	0.485	0.80	5.0	15.0	NIL	NIL
Cu	mg/l	0.0	0.10	0.008	0.02	0.05	1.5	4.7	NIL
Pb	µg/l	0.0	39.3	11.0	0.01	10.0	NR	42.3	NIL

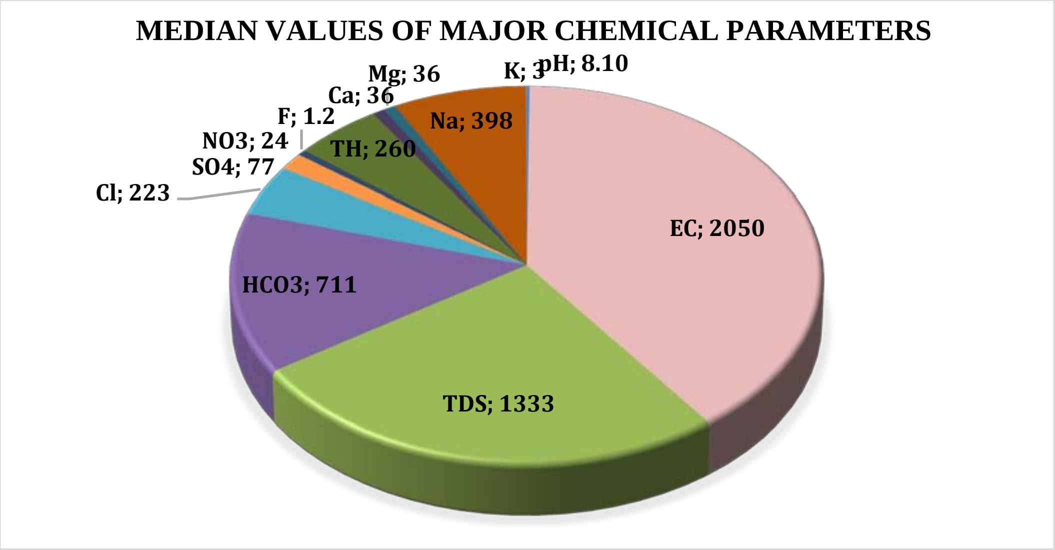

Figure 3: Pie Diagrams of Median values of cations and anions

The abundance of major cation concentration in the groundwater of the study area are in the order of $Na^+ > Mg^{2+} > Ca^{2+} > K^+$ shows that groundwater is dominated by alkali (Na) metal followed by alkaline earth (Ca & Mg). The anion chemistry of the analyzed samples shows that bicarbonate ion HCO_3^- is most dominating anion with the abundance order $HCO_3^- > Cl^- > SO_4^{2-} > NO_3^-$.

Heavy metals are the key indicators of anthropogenic impact having various sources like traffic activities, road runoff, dry ash deposition from burning plants, industrial effluents and landfill leachate. Thus, the monitoring of heavy metals contamination will be important to assess the landfill impact on groundwater quality. The chemical analysis of groundwater shows that heavy metals i.e. Cu, Zn, Fe, Ni and Pb, found in remarkable concentration. The concentration of Ni at sampling locations MH-5, MH-7 & MH-16 has exceeded the acceptable limit (0.02 mg/l) in 11.5% of total groundwater samples.23% of total groundwater samples have Fe greater than acceptable limit 1.0 mg/l may be due to the iron and tin-based waste in landfill site. The maximum concentration of Pb is observed at MH-16 with 39.3 μg/l and in about 42.3% of total groundwater samples exceeded the acceptable limit 10.0 μg/l may be due to presence of Pb based waste like electronic waste and lead plated materials, which is significant in the study area. Concentration of Zn and Cu in the study area varies from BDL to 3.5mg/l and BDL to 0.10 mg/l respectively, which is not objectionable as per BIS standard.

VI. STATISTICAL ANALYSIS

a) Correlation analysis (CA)

To understand the relationship between the measured values of various parameters and to test the significance, coefficient of correlation (r) was used. The Pearson's correlation matrix presented in table 2 was generated using the dataset of 18 hydro chemical parameters (pH, EC, TDS, HCO_3^-, NO_3^-, SO_4^{2-}, Cl^-, F^-, TH, Ca^{2+}, Mg^{2+}, Na^+ K^+ Fe, Zn, Cu, Ni, and Pb).

Table 2: Pearson's correlation matrix

	pH	*EC**	*CO3*	*HCO3*	*Cl**	*SO4*	*NO3**	*F**	*TH**	*Ca**	*Mg**	*Na**	*K**	*TDS*	*Fe*	*Ni*	*Cu*	*Zn*	*Pb*
pH	**1**																		
EC	-0.322	**1**																	
CO_3	0.347	-0.143	**1**																
HCO_3	0.277	**0.504****	0.067	**1**															
Cl	**-0.394***	**0.953****	**-0.16**	**0.272**	**1**														
SO_4	-0.442*	**0.881****	-0.18	0.229	**0.837****	**1**													
NO3	**-0.643****	0.289	-0.13	-0.079	0.233	0.471*	**1**												
F*	0.351	-0.055	0.023	0.195	-0.076	-0.172	-0.269	**1**											
TH*	**-0.728****	**0.595****	-0.23	-0.192	**0.667****	**0.753****	**0.688****	-0.28	**1**										
Ca*	**-0.646****	0.338	-0.14	-0.403*	0.475*	**0.509****	**0.621****	-0.2	**0.918****	**1**									
Mg*	**-0.687****	**0.758****	-0.28	0.06	**0.750****	**0.874****	**0.638****	-0.32	**0.912****	**0.673****									
Na*	-0.119	**0.958****	-0.06	**0.665****	**0.878****	**0.763****	0.113	0.046	0.347	0.087	**0.555****	**1**							
K*	-0.172	**0.524****	-0.08	-0.038	**0.603****	**0.523****	0.101	-0.24	**0.535****	0.488*	0.491*	0.409*	**1**						
TDS	-0.322	1	-0.14	**0.504****	**0.953****	**0.881****	0.289	-0.06	**0.595****	0.338	**0.758****	**0.958***	**0.524****	**1**					
Fe	0.064	-0.269	-0.1	-0.273	-0.206	-0.284	0.023	-0.19	-0.103	-0.039	-0.151	-0.288	-0.005	-0.27	**1**				
Ni	0.212	-0.179	-0.07	-0.093	-0.178	-0.121	-0.092	0.162	-0.17	-0.096	-0.216	-0.148	0.038	-0.18	0.134	**1**			
Cu	0.15	-0.222	-0.08	-0.247	-0.161	-0.231	-0.094	0.001	-0.051	0.015	-0.11	-0.262	0.15	-0.22	0.438*	**0.503****	**1**		
Zn	0.09	-0.19	-0.12	-0.277	-0.127	-0.131	-0.168	-0.1	-0.094	-0.095	-0.077	-0.205	-0.128	-0.19	**0.601****	0.084	0.37	**1**	
Pb	0.121	0.239	-0.17	0.181	0.237	0.16	-0.188	0.148	-0.001	-0.026	0.024	0.272	0.298	0.239	0.03	0.332	0.2	0.08	**1**

** Correlation is significant at the 0.05 level (2-tailed) ** Correlation is significant at the 0.01 level (2-tailed).*

The correlation matrix describes the interrelationship between variables [29]. The matrix depicts that pH has low to moderate correlation with all the major and minor ions. Total dissolved solid (TDS) has very high positive 2-tailed correlation with same 0.05 significance with Na^+ (r=0.958, $p <0.05$), Cl^- (r=0.953, $p<0.05$), SO_4^{2-} (r =0.881, $p <0.05$) and Mg^{2+} (r=0.758, $p <0.05$) signifying the contribution of these major ions to the TDS of the groundwater and also their role in major geochemical processes. The total hardness by virtue of its origin has a very high positive correlation with Ca^{2+} and Mg^{2+} with same significance (r=0.918 and 0.912 with $p <0.05$), respectively.

Similarly, Chloride specifies high to moderate positive correlation with Na^+, SO_4^{2-}, Mg^{2+}, TH and K^+ (r =0.878, 0.837, 0.750, 0.667 and 0.603 with $p <0.05$) respectively signifying the role of leachate around the dumping site that has enriched the groundwater with these salts. The strong correlation of sulphate with Na^+, Mg^{2+} (r=0.763, 0.874 with $p < 0.05$) and moderate correlation with Ca^{2+} and K^+ (r=0.509, 0.523 with $p <0.05$) shows enrichment of sulphate via degradation of organic waste from topsoil and sewage infiltration in groundwater that is produced by municipal waste during and after rainfall along with fertilizer application from nearby agriculture areas [30]. Nitrate is also a good indicator of anthropogenic pollution and in the study area it shows a moderate correlation with calcium and magnesium (r=0.621, 0.638 with $p <0.05$).

Heavy metal distribution is closely related to organic matter and other pollutants in leachates [31]. As such there is no strong correlation within heavy metals and remaining variables in the used dataset, but matrix shows a moderate correlation with same confidence level within Fe and Zn (r=0.601, $p < 0.05$) and Ni with Cu (r=0.601, $p < 0.05$) which reveals that the sources of these metals may be same or there may be process based relationship.

b) Principal Component Analysis (PCA)

The method of principal component analysis is a special case of the more general method of Factor Analysis. The characteristic of PCA is to transform the original variables into new, uncorrelated (orthogonal) variables, called the principal components. These new variables are a linear combination of the existing variables [32]. The first four principal components (PC1, PC2, PC3 and PC4) absorb and accounts for the maximum possible proportion of the total variance in the data set. The factor loadings (value close to ±1) indicate strong relationship (positive or negative) between the variable and the factor. PCA technique extracts the eigen values and eigen vectors from the covariance matrix of original variables.

The principal component analysis (PCA) was computed using 17 variables (pH, TDS, HCO_3^-, NO_3^-, SO_4^{2-}, Cl^-, F^-, TH, Ca^{2+}, Mg^{2+}, Na^+ K^+ Fe, Zn, Cu, Ni, and Pb) for all groundwater sampling locations. After computation, 17 PCs were obtained, but only four PCs with eigen value greater than 1 are significant and considered, because higher the eigen value of a PC, the greater the contribution of that particular PC to the variability of the groundwater chemistry [33].PCA results comprising eigen values, percentage of total variance and % cumulative variance are summarized in table 3 and factor loadings in all four principal components is given in table 4.

Table 3: Eigen value, variability and cumulative % of each extracted components

Component	Eigen value	Variability (%)	Cumulative (%)
PC1	6.490	38.175	38.175
PC 2	2.999	17.640	55.815
PC 3	2.148	12.637	68.452
PC 4	1.277	7.510	75.962
PC 5	0.902	5.309	81.271
PC 6	0.800	4.704	85.975
PC 7	0.632	3.717	89.691
PC 8	0.515	3.028	92.719
PC 9	0.392	2.303	95.023
PC 10	0.336	1.976	96.999
PC 11	0.178	1.045	98.044
PC 12	0.172	1.010	99.054
PC 13	0.118	0.693	99.747
PC 14	0.042	0.250	99.997
PC 15	0.000	0.003	100.000
PC 16	7.591E-5	0.000	100.000
PC 17	-4.729E-16	-2.782E-15	100.000

Components in bold are considered to be the most significant

The scree plot is a graphical method in which all eigen values are plotted in their decreasing order. The number of eigen values to the left of the point where the last substantial drop in the magnitude of eigen values appears suggests the number of components to retain [34]. The scree plot of the eigen values and components of the study area is presented in figure4.

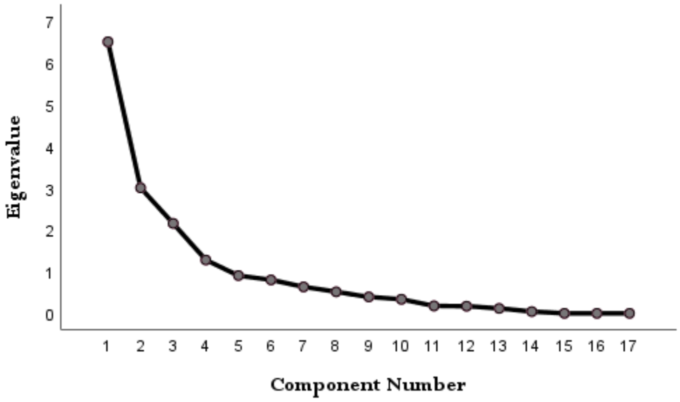

Figure 4: Scree plot of principal components

For the interpretation of factors, vaximax rotation technique is applied, which is the most popular rotation technique [35].PCA was calculated by using Varimax and Kaiser normalization method which extracted four main principal components cumulatively responsible for approximately 76% of the total variance in the hydrochemical data. Factor loadings are classified as 'strong', 'moderate' and 'weak' as per loading values of >0.75, 0.75–0.50 and 0.50–0.30, respectively [36]. The component plot in the rotated space is presented in figure 5.

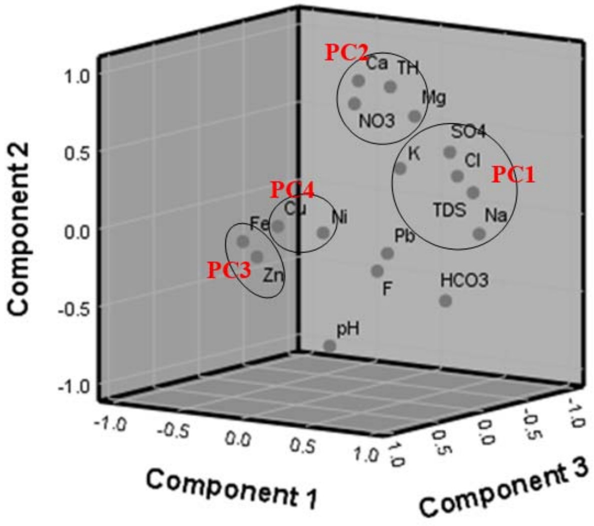

Figure 5: Component plot in rotated space for groundwater around the dumping site

The first component, PC1 with an eigen value of 6.49explains about 38.2% of the total variance and has strong positive loading (>0.75) for EC (0.95), Na$^+$ (0.97), Cl$^-$ (0.87), SO$_4^{2-}$ (0.78) and moderate positive loading for Mg^{2+} (0.59) and K$^+$ (0.50). PC1 thus corroborates with the results of CA that these major ions contribute positively to the total dissolved solids of the groundwater and decide the major water quality of the study area.

PC2 represents17.64 % of the total variance with an eigen value of approximately 3.0, which consists of a strong positive loading of TH (0.90), Ca^{2+} (0.91), Mg^{2+} (0.74) explained the direct relation of Ca-H and Mg-H that cumulatively contributes to TH of groundwater. Moderate positive loading of SO$_4^{2-}$ (0.51) and NO$_3^-$ (0.76) is due to sewage and anthropogenic activities in and around dumping site.

Component 3, PC3 having 12.63 % of the total variance with an eigen value of approximately 2.15. This component basically extracted because of two heavy metals Fe and Zn, have very strong loadings of 0.83 and 0.85 respectively.

Similarly, component 4, PC4 having 7.51 % of the total variance with eigen value of approximately 1.28 also extracted due to strong and moderate positive loadings of Ni (0.79) and Cu (0.68) heavy metals, favors the output of correlation analysis that the source and mobilization of these heavy metals is same. The presence of Fe, Zn, Ni and Cu in the study area could be attributed to the anthropogenic origin viz. domestic waste containing trash of these metals, industrial waste, atmospheric deposition and municipal sewage etc.

Table 4: Varimax rotated component matrix of groundwater samples

Variables	PC 1	PC 2	PC 3	PC 4	Communalities
pH	-0.093	-0.814	-0.005	0.212	0.716
TDS	0.949	0.265	-0.114	-0.036	0.984
HCO_3	0.629	-0.487	-0.263	-0.172	0.732
Cl	0.873	0.373	-0.046	0.037	0.905
SO_4	0.777	0.510	-0.099	-0.026	0.875
NO_3	0.065	0.758	-0.055	-0.173	0.612
F	-0.026	-0.387	-0.438	0.284	0.423
TH	0.378	0.905	-0.008	0.016	0.963
Ca	0.105	0.912	-0.043	0.127	0.860
Mg	0.594	0.742	0.030	-0.100	0.914
Na	0.970	-0.005	-0.152	-0.056	0.966
K	0.502	0.401	0.061	0.388	0.567
Fe	-0.185	-0.029	0.830	0.138	0.743
Ni	-0.163	-0.095	-0.032	0.792	0.664
Cu	-0.190	0.012	0.435	0.677	0.684
Zn	-0.065	-0.114	0.845	0.084	0.738
Pb	0.377	-0.165	0.023	0.630	0.567
Eigenvalue	6.490	2.999	2.148	1.277	
Variability (%)	38.175	17.640	12.637	7.510	
Cumulative (%)	38.175	55.815	68.452	75.962	

c) *Hierarchical Cluster Analysis (HCA)*

Hierarchical clustering analysis (HCA) is used for interpretation of data by clustering the samples and parameters that decide the geochemistry of particular study area. In clustering, Ward method with Euclidean distance is used to measure the similarity between various datasets. A graphical depiction of the hierarchical clustering along with the corresponding distance to reach a linkage is called Dendrogram. The dendrograms were prepared for Q mode considering the 17 variables and R-mode for all water samples.

d) *Q- mode hierarchical cluster analysis*

The emerged dendrogram shown in figure 6 reveals three distinct clusters for 17 chemical variables details of which is presented in table 5. These clusters suggest that there are three distinct sets of influences that affect the groundwater samples.

Cluster I signifies maximum variables viz. pH, Ca^{2+}, Mg^{2+}, K^+, SO_4^{2-}, NO_3^- and F^- which are perhaps due to the geogenic processes like weathering and dissolution of minerals and among heavy metals Fe, Zn, Pb, Ni, and Cu are expected due to the major anthropogenic contamination. Cluster II constitutes TH, Na^+, Cl^- and HCO_3^- which may be considered as carbonate hardness controlled cluster and gets impact from leachate infiltration. Cluster III represents of total dissolution of all ions (TDS) which is considered as salinity controlled cluster and helps to decide the degree of pollution of groundwater of the study area.

Table 5: Results of hierarchical cluster analysis of chemical variables

Cluster	Chemical variables
I	pH, F, K, Ca, Mg, NO_3, $SO_{4,}$ Fe, Zn, Pb, Ni, and Cu
II	Cl, Na, HCO_3, TH
III	TDS

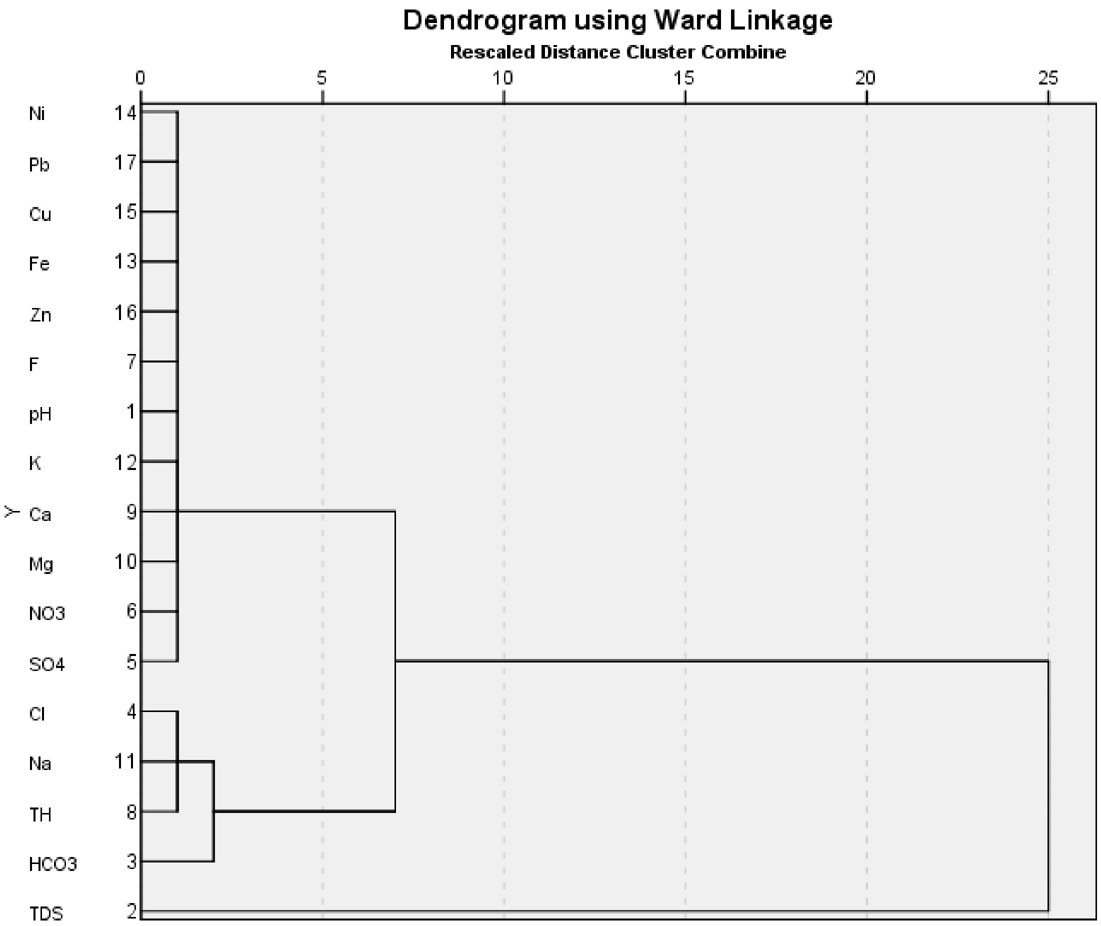

Figure 6: Dendrogram for 17 variables from cluster analysis in Q-mode

e) R- mode hierarchical cluster analysis

HCA of groundwater samples presented by Dendrogram for R mode analysis shown in figure 7 has also resulted in three statistically illustrated groups designated as Group I, Group II and Group III. Around 38.5% of the groundwater samples fall under the Group I, 46.2% under Group II and 15.3% under Group III. The average value for the quality parameters for each group is presented in table 6.

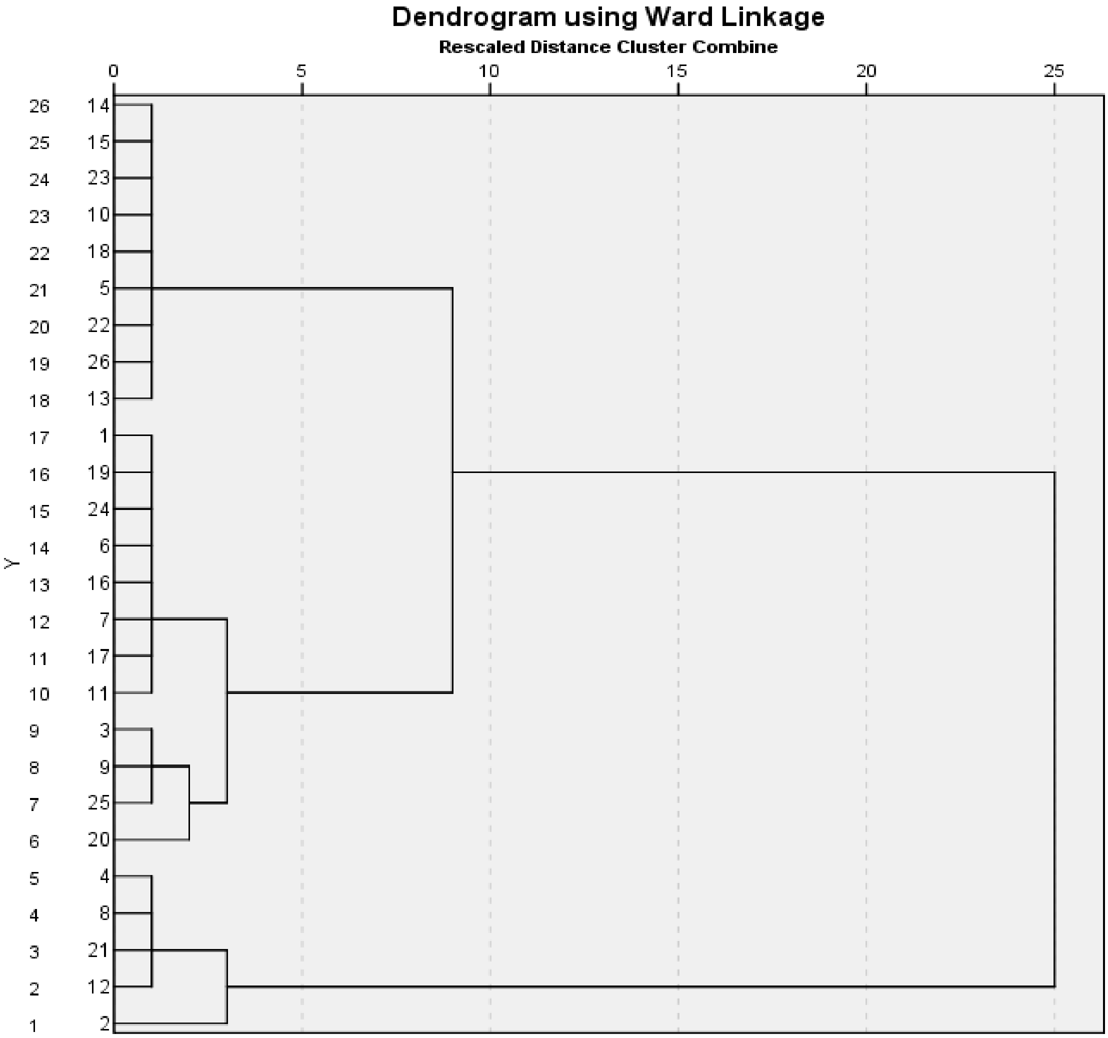

Figure 7: Dendrogram for 17 variables from cluster analysis in R-mode

Table of R mode reveals that Group I has 34.6% samples where the concentrations of all the parameters are within the permissible limit of BIS, 10500. Group II comprising 46.15% samples which have high average value of nitrate which is attributed to the anthropogenic pollution. In contrast to Group I & II, Group III is associated with very high TDS (average value 3019 mg/l) and also the concentrations of other chemical parameters exceed the permissible limits of BIS, 10,500. This group possesses high salinity and high concentrations of chloride, nitrate, calcium, and magnesium may be owed to excessive use of fertilizers in agricultural lands, dry ash deposition from burning plants, industrial effluents, domestic waste and landfill leachate.

Table 6: Average value for the water quality parameters for each Group

Group	pH	TDS	HCO_3	Cl	SO_4	NO_3	F	TH	Ca	Mg	Na	K	Fe	Zn	Pb	Ni	Cu
I	8.07	804	532	101	36	22.6	1.21	228	45	28.5	118	2.80	.989	0.60	.007	.006	0.01
II	8.03	1712	789	384	132	70.66	1.57	305	51	42.92	484	3.32	.559	0.32	.016	.004	0.01
III	7.82	3019	755	900	381	67.80	1.11	560	72	92.4	818	5.66	.077	0.55	.015	0.00	0.00

Bold indicates the highest average value parameters amongst different Groups.

VII. CONCLUSIONS

The chemical analysis of the groundwater samples collected from the study area revels the water quality of the area has an impact not only from the natural rock water interaction but also from the leachate generation from the dumping site which is infiltrating through the soil. About 65% samples are under hard to very hard category. TDS is very high owing to the major role of variables like Na^+, Cl^-, SO_4^{2-} and Mg^{2+} in turn contributing to the various geochemical processes. The positive correlation of Cl^- with Na^+, SO_4^{2-}, Mg^{2+}, TH and

K^+ is indicating the impact of leachate. The infiltration and enrichment from organic degradation is reflected by SO_4^{2} with its strong correlation with Na and Mg and moderate correlation with Ca^{2+} and K^+. High Nitrate is directly pointing towards the anthropogenic actions. With the aid of PCA, total four PC's are extracted which account for 76% of total variance of hydrochemical data of the study area. PC1 decides the major quality of the groundwater of the study area having 38.2% total variance. PC2 has 17.64% total variance which has strong positive loadings of TH, Mg and Ca and moderate positive loadings of SO_4^{2-} and NO_3^{2-}. PC3 and PC4 having total variance of 12.63% and 7.51% having strong loadings of heavy metals Fe & Zn and Ni & Cu respectively. The dendrograms of Q and R modes classifies the chemical parameters and groundwater samples in three clusters each which directly indicates the alteration water quality of the study area not only geogenic but also due to intrusion of the contaminants generated by the anthropogenic activities in the area especially the dumping of Municipal Solid Waste. The three clusters formed in Q mode in HCA are affected by bicarbonate ion, salinity and hardness and TDS.

In wrapping up and arriving to the conclusion of all analysis indicates that lining system and collection of leachates followed by its proper treatment is required with regular monitoring of the air, soil and water quality parameters. Municipal corporation shall device apposite combination of technology to segregate the waste, make reuse of waste, processing of organic waste, restricting bio-medical waste disposal so as to minimalize the load on the dumping site. If not, these pollutants can be hazardous both for human health and agricultural products in irrigated areas.

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Assessment of the Water Quality of Some Sulfur Springs in the Bashtabia Area within the City of Mosul

By Hadeel Bassam Yahya, Yussra Majed Alshaker & Rawaa Mahmood Hamoshi

Abstract- The research aims to conduct a monthly study of water quality by conducting several physical and chemical tests for sulfur spring water in the Bashtabiya Castle area, which is located on the western bank of the Tigris River in the city of Mosul, and for that, monthly samples were collected from three springs for five months during the period from October The second is 2020 until March 2021.

Keywords: sulfur spring bashtabia area water quality.

GJSFR-H Classification: DDC Code: 363.739460973 LCC Code: TD223

Assessment of the Water Quality of Some Sulfur Springs in the Bashtabia Area within the City of Mosul

Hadeel Bassam Yahya [α], Yussra Majed Alshaker [σ] & Rawaa Mahmood Hamoshi [ρ]

Abstract- The research aims to conduct a monthly study of water quality by conducting several physical and chemical tests for sulfur spring water in the Bashtabiya Castle area, which is located on the western bank of the Tigris River in the city of Mosul, and for that, monthly samples were collected from three springs for five months during the period from October The second is 2020 until March 2021.

Which included temperature, electrical conductivity, dissolved solids, pH, total hardness, total alkalinity, sulfate ions, phosphates, sodium and potassium, oils and greases, as well as biological tests represented by the total count of bacteria, where the temperature rates ranged between (21.74-22.04) C, the electrical conductivity rates were (5158.59-5521,795) micromoz/ cm, while the total dissolved solids rates were between (2579.6-2761 mg/L), and the pH ranged between (6.9-7) during the study period as for the total hardness It was (2080-2220) mg/l in terms of calcium carbonate, as the results showed the total alkalinity rates, which were between (452- 649) mg/l, while sulfate ions averaged (2310.8-2365.3) mg/l, phosphate ions ranged between (0.02154-0.04482) mg/L, and for sodium and potassium ions, their rates ranged between (376-447.6) (31.4-36.2) mg/L, respectively. As for oils, the results showed that their rates were (0.1696-0.1848) mg/L. And the total count of bacteria ranged from the stomach During the study period, between (0.5 - 3.25) cells/ml.

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I. INTRODUCTION

Groundwater is the water that moves and collects in the ground within the geological formations and soil layers, which directly affects the properties of this water (Mohammed, 2015). The amount of water drainage from the springs varies, and the different sources of this water pass through the pores of the soil, which filters its contents and dissolves many salts and elements in it, giving it a high percentage of salinity. That is why it is called mineral water and it is also known as hot water because of its high temperature (Al-Zamili and Al-Asadi, 2014).

Spring water flows from under the surface of the earth and is formed naturally in special water tanks that do not mix with surface water and do not need to make changes or add chemicals. The chemistry of mineral water and its volume change from one place to another according to the conditions of its formation and the type of formation layers in which this water is stored (Matar and others, 2009). A liter of water (Al Taweel, 2017), the layers of gypsum rocks, and the crater located under the surface of the earth provided a suitable environment for the formation of sulfur supported by special types of anaerobic bacteria, as H_2S gas is released, which interacts with the oxygen dissolved in the water to form sulfuric acid H_2SO_4, thus forming acidic sulfur water There are two sources of liberated H_2S gas, the first represented by gas mainly located in the depths and its quantity is small compared to the second source, which is due to bacterial activity, and as products of sulfur formation and reduction resulting from sulfates, the produced gas is oxidized in the presence of special types of bacteria to form sulfuric acid H_2SO_4 (Aswad et al., 2018).

II. STUDY AREA

The study area included a number of sulfur springs, which are located on the western bank of the Tigris River in the city of Mosul, which is close to the Bashtabiya Castle. Monthly models were taken to study three hot and cold sulfur springs, Table (1). The study area is characterized by a hot, dry climate in summer and cold and rainy in winter, according to the data of the weather station in Mosul.

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Table 1: Shows the location of the sulfur springs near the castle of Bashtabia

Spring name and their locations	Locations		
		E	N
Bashtabiya	1	43˚ °12'00"96	36°35'67"51
	2	43˚ °12'01"60	36°35'67"63
	3	43˚ °12'00"78	36°35'67"75

III. SAMPLE COLLECTION

Fifteen water samples were collected at a rate of 3 samples per month from three springs near the castle of Bashtabyia (3 samples / spring) for a period of five months during the period from November 2020 to March 2021 using sterile polyethylene bottles of 250 ml capacity for biological tests and a capacity of 2 liters for chemical and physical tests By immersing the bottle after homogenizing it several times gradually so that its direction faces the flow of water, where the sample was taken and its nozzle was re-sealed tightly inside the water and closed with aluminum foil tightly closed and was kept in a box of iced cork until it was transferred to the laboratory for biological, chemical and physical tests.

Image 1: The first location Image (2) the second location Image (3) the third location

IV. METHODS

a) Physical tests

It includes the measurement of temperature using an alcohol thermometer, measured in degrees, the measurement of total dissolved solids using a T.D.S meter, and electrical conductivity using an E.C meter in micromoz/cm.

b) Chemical tests

The measurement of the pH using a pH meter after regulating it with buffer solutions includes the total hardness by scavenging with Na_2EDTA, the total alkalinity by the guide method, and the determination of sulfate and phosphate by the spectrophotometer, as well as the determination of sodium and potassium ions using a photometric spectrometer The flame photometer expressed the concentration in mg/l, and finally measured the oils and greases.

c) Biological tests

Bacteriological tests were represented by the total count of bacteria by making a dilution of each sample to a dilution (10^{-5}) with a solution of physiological salt (Normal slain), and placing 1 ml of each of the dilution (10^{-3}, 10^{-4}, 10^{-5}) in a dish. A sterile petri, pour the cooled and sterile Nutrient Agar into the dish and move the plate in the form of No. 8 until the sample is homogeneous and after solidification of the medium is placed upside down in the incubator and incubated aerobically and anaerobic at a temperature of 37 ° C for 24-48 hours.

V. RESULT & DISCUSSION

Water quality depends on the different physical, chemical and biological properties of water, as well as the standard specifications used to measure water quality (Al-Lahibi, 2021).

a) Physical tests

i. *Tempreture*

Temperature is one of the most important indicators of water quality that affects the physical and chemical properties of water (Larnier et al. 2010). The average temperature ranged between (21.74-22.04) C, the highest rate was in site No. 1 or the lowest was in site 3. The reason for the high temperature of this water is attributed to the chemical reactions that emit heat that accompany the dissolution of the mineral materials that make up gypsum rocks and dolomite when the water of Al-Ayoun passes through it (Al-Hamdani, 2020). As shown in Table No. 2 and Figure.

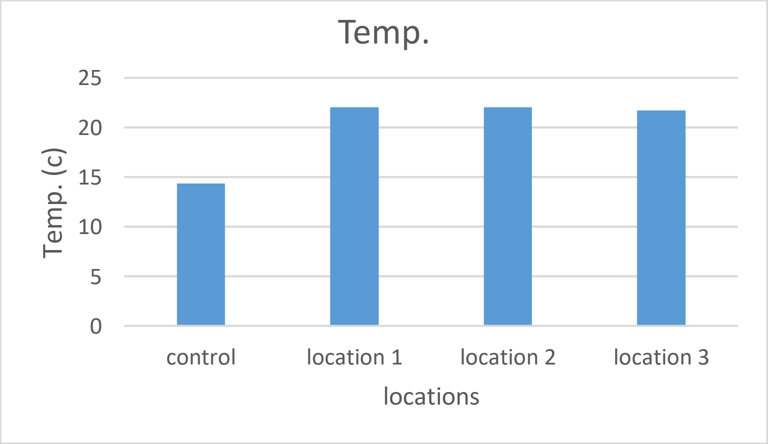

Figure 2: Averages of the temperature of the studied spring water (°C)

ii. *Electric Conductivity*

Electrical conductivity is the ability of water to transmit electric current and depends on the concentration of dissolved ions in the water and temperature, as it is directly proportional to them (Al-Hamdani, 2020). Its rates reached (5158.59- 5521.795) micromoz/cm. The highest rate was in Site 3 and the lowest was in Site 1, as shown in Table 2 and Figure 3. The reason may be due to the rocky nature of the geological formations of the studied areas (Al-Saffawi, 2019).

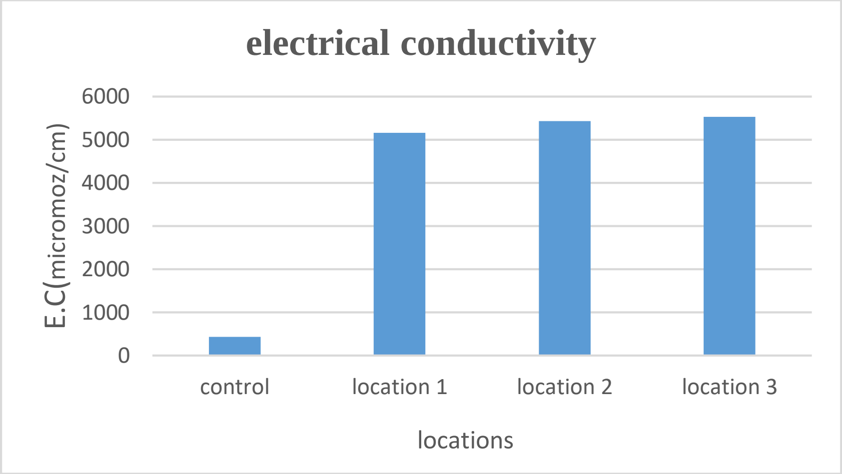

Figure 3: The electrical conductivity rate of the studied spring water (micromoz/cm)

iii. *Total Dissolved Solid*

Solids in water represent an important indicator to know the amount of substances or molecules in water, and they include different substances, organic and inorganic substances, or they may be in the form of solid substances dissolved in water consisting of negative ions of compounds combined with ions of positive elements (Bee, 2005). The rates of total dissolved solids were between (2579.6- 2761) mg/L, where the highest value was reached in Site 3 and the lowest in Site 1. The reason may be due to the difference in the geological formations of the layers through which the water passes (Al-Hamdani, 2020). As shown in Table 2 and Figure 4.

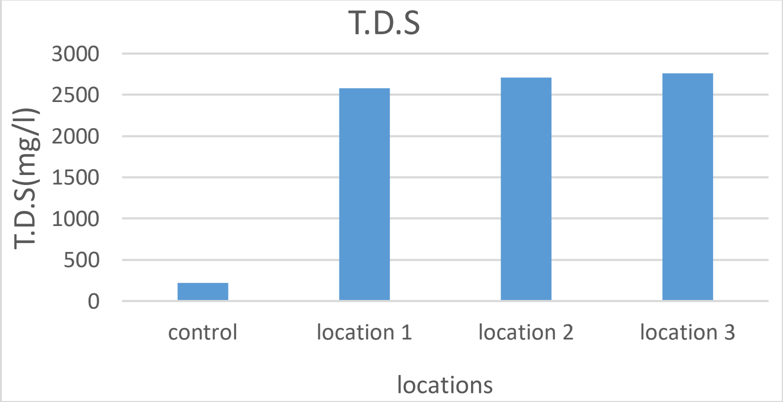

Figure 4: Total Dissolved Solids (TDS) of the studied spring water (mg/L)

b) *Chemical Tests*

i. *pH*

It is evident from Table (2) and Figure (5) that the rates were between (6.9-7), the highest rate in site 3 and the lowest in site 2. The reason may be due to the neutralization of the acidity of water and soil with carbonates and bicarbonate salts (Al-Safawi et al., 2018), and the decrease is due to Some values refer to the biological processes of oxidation and decomposition of organic matter when the oxygen concentration drops to critical levels, thus forming a number of carboxylic and acidic compounds (Sharaky & Abdoun, 2020).

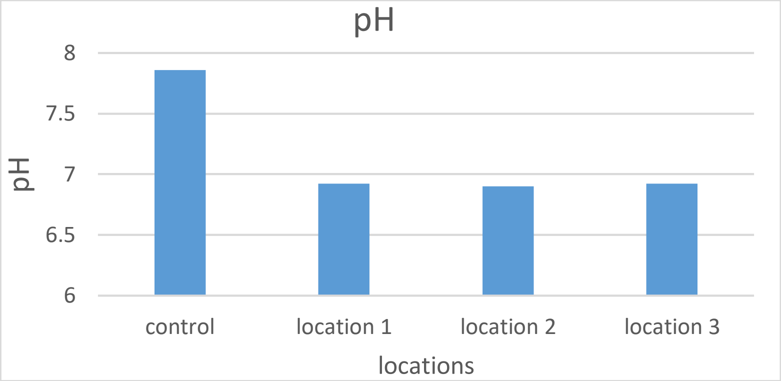

Figure 5: Averages of the pH function of the studied springs water

ii. *Total Alkalinity*

The alkalinity is the amount of negative ions present in water and the resistance to hydrogen ion, and thus it is a measure of water's susceptibility to acidity (Moses & Ishaku, 2020); The results showed the total alkalinity rates, which were between (452-649 mg/L), where the highest value was in site 3 and the lowest value in site 2. The reason for the presence of alkalinity in water is the presence of carbonate, bicarbonate and hydroxide ions. Bicarbonate ion due to the pH values not exceeding 8.3 (Fadipe & Oladepo, 2020). As shown in Figure (6) and Table (2).

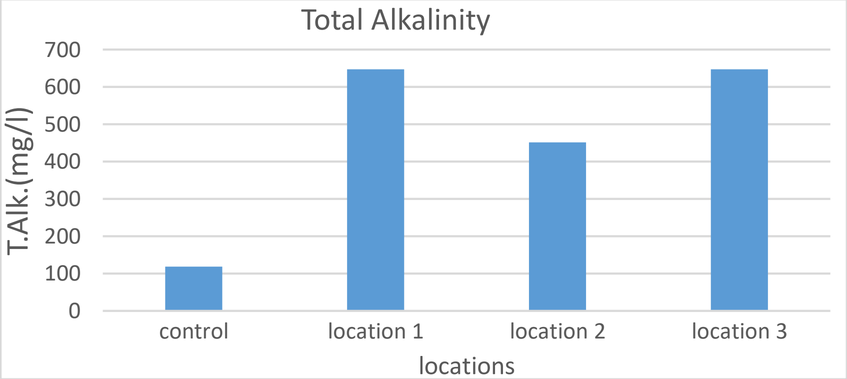

Figure 6: The total alkalinity of the studied spring water (mg/L)

iii. *Total Hardness*

Total hardness is a relative indicator to know the total dissolved solids. Calcium, magnesium, and bicarbonate ions make up the majority of the total dissolved solids. Hardness expresses the water's suitability. Less than that, its effect will be limited (Merdhah and Yassin, 2007; Al-Lahibi, 2021). It was (2080-2220) mg/L in terms of $CaCO_3$, the highest rate was in site 2 and the lowest in site 3 as shown in Table 2 and Figure 7. The reason for the presence of total hardness in water is the positive ions, especially calcium and magnesium ions (Verma et. al., 2018; Al-Hamdani, 2020).

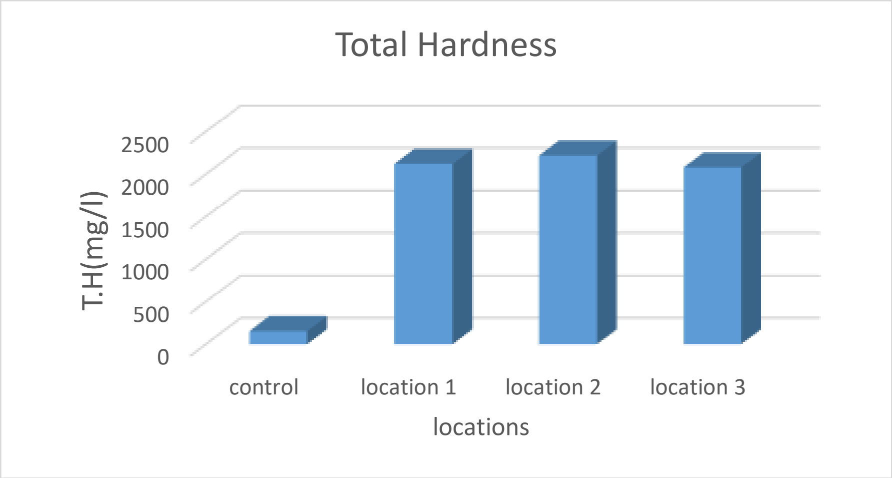

Figure 7: The total hardness of the studied water (mg/L)

iv. *Sulphate Ions*

It is evident from Table 2 and Figure 8 that the sulfate ion rates ranged between (2310.8-2365.3) mg/L, as the highest rate was in Site 1, while the lowest was in Site 3. The reason for the presence of sulfate ion concentrations is due to the nature of the geological rocks through which the water passes. The dissolution of gypsum rocks and weathering processes is the main reason for the increase in sulfate concentrations in the study area (Egbueri et. al., 2019), as well as the exposure of some sulfur minerals to oxidative conditions in the presence of water and Thiobacillus ferrooxidans bacteria that leads to the liberation of ions of some chemical elements and the formation of acid. Dilute sulfuric in sulfuric water (Duruibe et al. 2007).

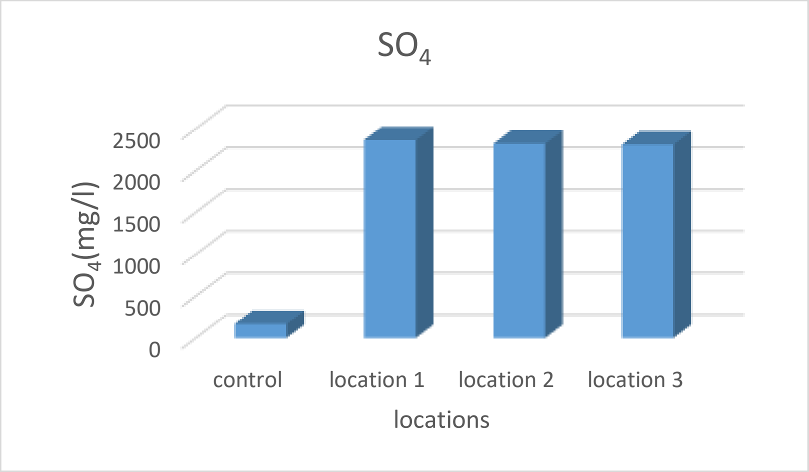

Figure 8: Sulfate ion rate for the studied spring water (mg/L)

v. *Phosphate Ions*

The results of the study showed that the phosphate ion rate was between (0.0215- 0.0448) mg/L as shown in Figure 9 and Table 2, where the highest value was in Site 2 and the lowest in Site 1 and the reason for the decrease in these values may be due to the ability to precipitate phosphate in the form of calcium phosphate $Ca_3 (PO_4)_2$ as well as its adsorption by some clay minerals and organic compounds, which reduces its transfer to the aquatic environment (Ohwoghere-Asuma et. al., 2020).

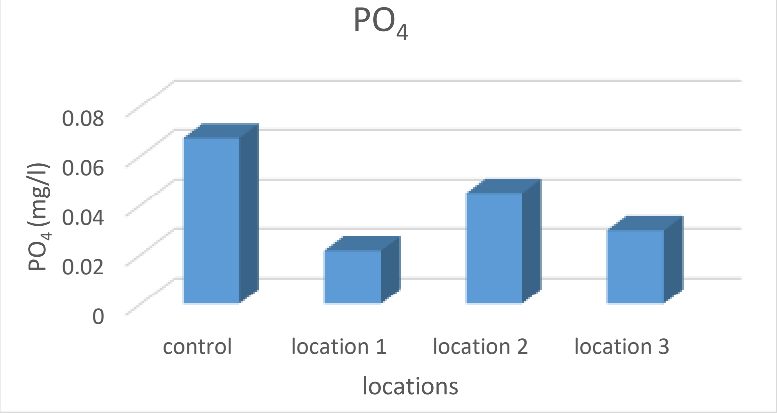

Figure 9: Phosphate ion rate of the studied spring water (mg/L)

vi. *Sodium and Potassium Ions*

Figure 10 and Table 2 show that the highest rate of sodium and potassium ion is in site 3, while the lowest is in site one, as their rates ranged between (376-447) and (31.4-36.2) mg / liter, respectively. The reason for the presence of sodium ion may be attributed to the nature of geological formations For the earth layers through which water passes, as well as the processes of weathering, when water reaches the sod minerals, sodium ions will be released (Hui, 2020). As for the presence of potassium ion in these low concentrations compared to sodium, it is due to its adsorption by soil particles within the geological layers of the studied areas (Ibrahim & Nofal, 2020).

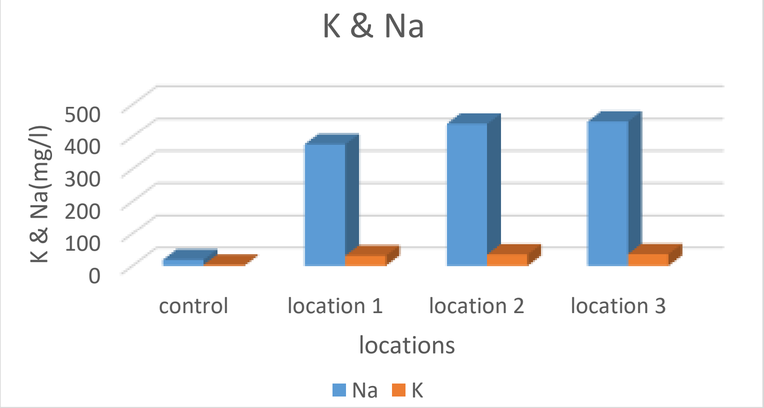

Figure 10: Average of sodium and potassium ions for the studied spring water (mg/L)

vii. *Oil and Grease*

The results of the current study indicated the concentration rates of oils and greases in the studied sulfur springs, which ranged between (0.169-0.184) mg/L, and the superiority of site 1 in the concentration of oils and grease and the lowest average concentrations in site 2 that the presence of oils and grease in water may indicate that these The water is coming from layers that contain oil, as evidence of the presence of bitumen, because the bitumen is one of the oil derivatives (Mahmoud et al., 2006), as shown in Table (2) and Figure (11).

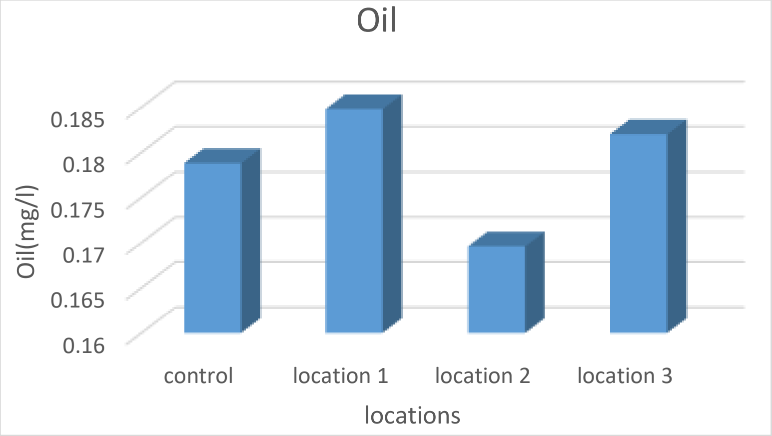

Figure 11: Oil rate of the studied springs water (mg/L)

c) *Biological tests*

i. *Total Plate Count*

Tests of the total number of bacteria are among the important indicators that include total aerobic, facultative and non-autotrophic bacteria. These numbers are usually approximate, but most of them are due to the inability to provide a nutrient medium and suitable conditions for the growth of all species (Juma, 2017). Through the results, it is clear that the number of bacteria exceeded the limit allowed by the World Health Organization, which ranged between (0.5-3.25) cells / ml. The highest rate was in site 1 and the lowest in site 2 as shown in Table 3 and Figure 11. The increase in bacterial numbers coincided With the high temperatures, which are suitable for the growth and reproduction of bacteria, and the low temperature in the winter season, their numbers decreased (Al-Omar, 2010).

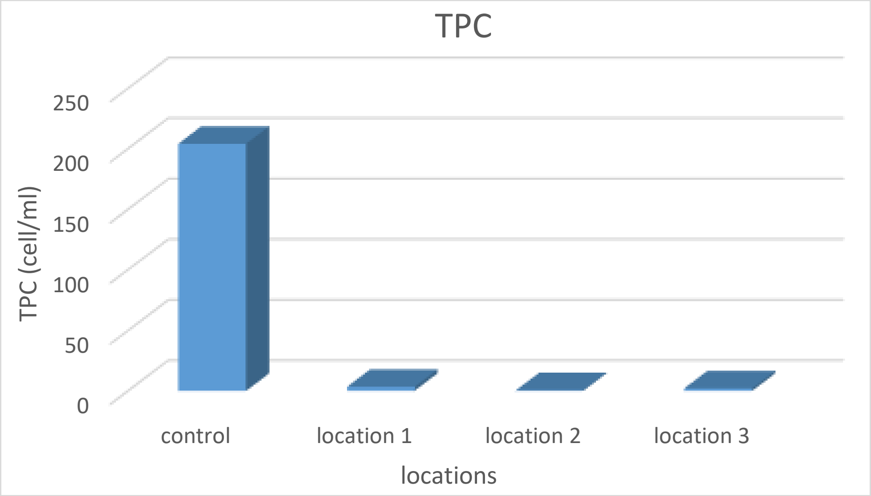

Figure 11: Average total number of bacteria in the studied spring water (cell/ml)

Table 2: Rate of physical and chemical tests of spring water

Test location	Temp.	pH	E.C	T.D.S	T.Alk.	T.H	SO$_4$-2	PO$_4$-3	Na$^+$	K$^+$	Oil
control	14.34	7.86	435.719	217.8	119	154.8	166.9	0.067	18.8	2.48	0.1788
location 1	22.04	6.92	5158.59	2579.6	648	2120	2365.3	0.02154	376	31.4	0.1848
location 2	22.02	6.9	5423.23	2711.8	452	2220	2322.6	0.04482	440.6	34.8	0.1696
location 3	21.74	7	5521.8	2761	649	2080	2310.8	0.0296	447.8	36.2	0.182

Table 3: Total number of bacteria (TPC) x 10^5cells.ml^{-1}

TPC						
MON. LOC.	11	12	1	2	3	AVG.
Control	HEAVY	295	280	115	126	204
LOC. 1	2	0	5	4	4	3.25
LOC. 2	1	0	0	2	0	0.5
LOC. 3	5	2	1	5	0	2

VI. Conclusion

The water is of a moderate type of acidic water, and this water is important for the recovery of diseases due to its high content of sulfates and its high temperature. at the optimum interest. It is considered unfit for drinking if we take into account the concentration of sulfates without regard to the rest of the characteristics. It contains more than 400 mg / liter in addition to the taste and smell. It is also characterized by being very hard because it contains concentrations higher than 180 mg / liter and with high salinity because it contains calcium and magnesium salts.

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Global Journals is in partnership with various universities, laboratories, and other institutions worldwide in the research domain. Authors are requested to disclose their source of funding during every stage of their research, such as making analysis, performing laboratory operations, computing data, and using institutional resources, from writing an article to its submission. This will also help authors to get reimbursements by requesting an open access publication letter from Global Journals and submitting to the respective funding source.

PREPARING YOUR MANUSCRIPT

Authors can submit papers and articles in an acceptable file format: MS Word (doc, docx), LaTeX (.tex, .zip or .rar including all of your files), Adobe PDF (.pdf), rich text format (.rtf), simple text document (.txt), Open Document Text (.odt), and Apple Pages (.pages). Our professional layout editors will format the entire paper according to our official guidelines. This is one of the highlights of publishing with Global Journals—authors should not be concerned about the formatting of their paper. Global Journals accepts articles and manuscripts in every major language, be it Spanish, Chinese, Japanese, Portuguese, Russian, French, German, Dutch, Italian, Greek, or any other national language, but the title, subtitle, and abstract should be in English. This will facilitate indexing and the pre-peer review process.

The following is the official style and template developed for publication of a research paper. Authors are not required to follow this style during the submission of the paper. It is just for reference purposes.

Manuscript Style Instruction (Optional)

- Microsoft Word Document Setting Instructions.
- Font type of all text should be Swis721 Lt BT.
- Page size: 8.27" x 11'", left margin: 0.65, right margin: 0.65, bottom margin: 0.75.
- Paper title should be in one column of font size 24.
- Author name in font size of 11 in one column.
- Abstract: font size 9 with the word "Abstract" in bold italics.
- Main text: font size 10 with two justified columns.
- Two columns with equal column width of 3.38 and spacing of 0.2.
- First character must be three lines drop-capped.
- The paragraph before spacing of 1 pt and after of 0 pt.
- Line spacing of 1 pt.
- Large images must be in one column.
- The names of first main headings (Heading 1) must be in Roman font, capital letters, and font size of 10.
- The names of second main headings (Heading 2) must not include numbers and must be in italics with a font size of 10.

Structure and Format of Manuscript

The recommended size of an original research paper is under 15,000 words and review papers under 7,000 words. Research articles should be less than 10,000 words. Research papers are usually longer than review papers. Review papers are reports of significant research (typically less than 7,000 words, including tables, figures, and references)

A research paper must include:

a) A title which should be relevant to the theme of the paper.
b) A summary, known as an abstract (less than 150 words), containing the major results and conclusions.
c) Up to 10 keywords that precisely identify the paper's subject, purpose, and focus.
d) An introduction, giving fundamental background objectives.
e) Resources and techniques with sufficient complete experimental details (wherever possible by reference) to permit repetition, sources of information must be given, and numerical methods must be specified by reference.
f) Results which should be presented concisely by well-designed tables and figures.
g) Suitable statistical data should also be given.
h) All data must have been gathered with attention to numerical detail in the planning stage.

Design has been recognized to be essential to experiments for a considerable time, and the editor has decided that any paper that appears not to have adequate numerical treatments of the data will be returned unrefereed.

i) Discussion should cover implications and consequences and not just recapitulate the results; conclusions should also be summarized.
j) There should be brief acknowledgments.
k) There ought to be references in the conventional format. Global Journals recommends APA format.

Authors should carefully consider the preparation of papers to ensure that they communicate effectively. Papers are much more likely to be accepted if they are carefully designed and laid out, contain few or no errors, are summarizing, and follow instructions. They will also be published with much fewer delays than those that require much technical and editorial correction.

The Editorial Board reserves the right to make literary corrections and suggestions to improve brevity.

FORMAT STRUCTURE

It is necessary that authors take care in submitting a manuscript that is written in simple language and adheres to published guidelines.

All manuscripts submitted to Global Journals should include:

Title

The title page must carry an informative title that reflects the content, a running title (less than 45 characters together with spaces), names of the authors and co-authors, and the place(s) where the work was carried out.

Author details

The full postal address of any related author(s) must be specified.

Abstract

The abstract is the foundation of the research paper. It should be clear and concise and must contain the objective of the paper and inferences drawn. It is advised to not include big mathematical equations or complicated jargon.

Many researchers searching for information online will use search engines such as Google, Yahoo or others. By optimizing your paper for search engines, you will amplify the chance of someone finding it. In turn, this will make it more likely to be viewed and cited in further works. Global Journals has compiled these guidelines to facilitate you to maximize the web-friendliness of the most public part of your paper.

Keywords

A major lynchpin of research work for the writing of research papers is the keyword search, which one will employ to find both library and internet resources. Up to eleven keywords or very brief phrases have to be given to help data retrieval, mining, and indexing.

One must be persistent and creative in using keywords. An effective keyword search requires a strategy: planning of a list of possible keywords and phrases to try.

Choice of the main keywords is the first tool of writing a research paper. Research paper writing is an art. Keyword search should be as strategic as possible.

One should start brainstorming lists of potential keywords before even beginning searching. Think about the most important concepts related to research work. Ask, "What words would a source have to include to be truly valuable in a research paper?" Then consider synonyms for the important words.

It may take the discovery of only one important paper to steer in the right keyword direction because, in most databases, the keywords under which a research paper is abstracted are listed with the paper.

Numerical Methods

Numerical methods used should be transparent and, where appropriate, supported by references.

Abbreviations

Authors must list all the abbreviations used in the paper at the end of the paper or in a separate table before using them.

Formulas and equations

Authors are advised to submit any mathematical equation using either MathJax, KaTeX, or LaTeX, or in a very high-quality image.

Tables, Figures, and Figure Legends

Tables: Tables should be cautiously designed, uncrowned, and include only essential data. Each must have an Arabic number, e.g., Table 4, a self-explanatory caption, and be on a separate sheet. Authors must submit tables in an editable format and not as images. References to these tables (if any) must be mentioned accurately.

Figures

Figures are supposed to be submitted as separate files. Always include a citation in the text for each figure using Arabic numbers, e.g., Fig. 4. Artwork must be submitted online in vector electronic form or by emailing it.

PREPARATION OF ELETRONIC FIGURES FOR PUBLICATION

Although low-quality images are sufficient for review purposes, print publication requires high-quality images to prevent the final product being blurred or fuzzy. Submit (possibly by e-mail) EPS (line art) or TIFF (halftone/ photographs) files only. MS PowerPoint and Word Graphics are unsuitable for printed pictures. Avoid using pixel-oriented software. Scans (TIFF only) should have a resolution of at least 350 dpi (halftone) or 700 to 1100 dpi (line drawings). Please give the data for figures in black and white or submit a Color Work Agreement form. EPS files must be saved with fonts embedded (and with a TIFF preview, if possible).

For scanned images, the scanning resolution at final image size ought to be as follows to ensure good reproduction: line art: >650 dpi; halftones (including gel photographs): >350 dpi; figures containing both halftone and line images: >650 dpi.

Color charges: Authors are advised to pay the full cost for the reproduction of their color artwork. Hence, please note that if there is color artwork in your manuscript when it is accepted for publication, we would require you to complete and return a Color Work Agreement form before your paper can be published. Also, you can email your editor to remove the color fee after acceptance of the paper.

TIPS FOR WRITING A GOOD QUALITY SCIENCE FRONTIER RESEARCH PAPER

Techniques for writing a good quality Science Frontier Research paper:

1. Choosing the topic: In most cases, the topic is selected by the interests of the author, but it can also be suggested by the guides. You can have several topics, and then judge which you are most comfortable with. This may be done by asking several questions of yourself, like "Will I be able to carry out a search in this area? Will I find all necessary resources to accomplish the search? Will I be able to find all information in this field area?" If the answer to this type of question is "yes," then you ought to choose that topic. In most cases, you may have to conduct surveys and visit several places. Also, you might have to do a lot of work to find all the rises and falls of the various data on that subject. Sometimes, detailed information plays a vital role, instead of short information. Evaluators are human: The first thing to remember is that evaluators are also human beings. They are not only meant for rejecting a paper. They are here to evaluate your paper. So present your best aspect.

2. Think like evaluators: If you are in confusion or getting demotivated because your paper may not be accepted by the evaluators, then think, and try to evaluate your paper like an evaluator. Try to understand what an evaluator wants in your research paper, and you will automatically have your answer. Make blueprints of paper: The outline is the plan or framework that will help you to arrange your thoughts. It will make your paper logical. But remember that all points of your outline must be related to the topic you have chosen.

3. Ask your guides: If you are having any difficulty with your research, then do not hesitate to share your difficulty with your guide (if you have one). They will surely help you out and resolve your doubts. If you can't clarify what exactly you require for your work, then ask your supervisor to help you with an alternative. He or she might also provide you with a list of essential readings.

4. Use of computer is recommended: As you are doing research in the field of science frontier then this point is quite obvious. Use right software: Always use good quality software packages. If you are not capable of judging good software, then you can lose the quality of your paper unknowingly. There are various programs available to help you which you can get through the internet.

5. Use the internet for help: An excellent start for your paper is using Google. It is a wondrous search engine, where you can have your doubts resolved. You may also read some answers for the frequent question of how to write your research paper or find a model research paper. You can download books from the internet. If you have all the required books, place importance on reading, selecting, and analyzing the specified information. Then sketch out your research paper. Use big pictures: You may use encyclopedias like Wikipedia to get pictures with the best resolution. At Global Journals, you should strictly follow here.

6. Bookmarks are useful: When you read any book or magazine, you generally use bookmarks, right? It is a good habit which helps to not lose your continuity. You should always use bookmarks while searching on the internet also, which will make your search easier.

7. Revise what you wrote: When you write anything, always read it, summarize it, and then finalize it.

8. Make every effort: Make every effort to mention what you are going to write in your paper. That means always have a good start. Try to mention everything in the introduction—what is the need for a particular research paper. Polish your work with good writing skills and always give an evaluator what he wants. Make backups: When you are going to do any important thing like making a research paper, you should always have backup copies of it either on your computer or on paper. This protects you from losing any portion of your important data.

9. Produce good diagrams of your own: Always try to include good charts or diagrams in your paper to improve quality. Using several unnecessary diagrams will degrade the quality of your paper by creating a hodgepodge. So always try to include diagrams which were made by you to improve the readability of your paper. Use of direct quotes: When you do research relevant to literature, history, or current affairs, then use of quotes becomes essential, but if the study is relevant to science, use of quotes is not preferable.

10. Use proper verb tense: Use proper verb tenses in your paper. Use past tense to present those events that have happened. Use present tense to indicate events that are going on. Use future tense to indicate events that will happen in the future. Use of wrong tenses will confuse the evaluator. Avoid sentences that are incomplete.

11. Pick a good study spot: Always try to pick a spot for your research which is quiet. Not every spot is good for studying.

12. Know what you know: Always try to know what you know by making objectives, otherwise you will be confused and unable to achieve your target.

13. Use good grammar: Always use good grammar and words that will have a positive impact on the evaluator; use of good vocabulary does not mean using tough words which the evaluator has to find in a dictionary. Do not fragment sentences. Eliminate one-word sentences. Do not ever use a big word when a smaller one would suffice.

Verbs have to be in agreement with their subjects. In a research paper, do not start sentences with conjunctions or finish them with prepositions. When writing formally, it is advisable to never split an infinitive because someone will (wrongly) complain. Avoid clichés like a disease. Always shun irritating alliteration. Use language which is simple and straightforward. Put together a neat summary.

14. Arrangement of information: Each section of the main body should start with an opening sentence, and there should be a changeover at the end of the section. Give only valid and powerful arguments for your topic. You may also maintain your arguments with records.

15. Never start at the last minute: Always allow enough time for research work. Leaving everything to the last minute will degrade your paper and spoil your work.

16. Multitasking in research is not good: Doing several things at the same time is a bad habit in the case of research activity. Research is an area where everything has a particular time slot. Divide your research work into parts, and do a particular part in a particular time slot.

17. Never copy others' work: Never copy others' work and give it your name because if the evaluator has seen it anywhere, you will be in trouble. Take proper rest and food: No matter how many hours you spend on your research activity, if you are not taking care of your health, then all your efforts will have been in vain. For quality research, take proper rest and food.

18. Go to seminars: Attend seminars if the topic is relevant to your research area. Utilize all your resources.

19. Refresh your mind after intervals: Try to give your mind a rest by listening to soft music or sleeping in intervals. This will also improve your memory. Acquire colleagues: Always try to acquire colleagues. No matter how sharp you are, if you acquire colleagues, they can give you ideas which will be helpful to your research.

20. Think technically: Always think technically. If anything happens, search for its reasons, benefits, and demerits. Think and then print: When you go to print your paper, check that tables are not split, headings are not detached from their descriptions, and page sequence is maintained.

21. Adding unnecessary information: Do not add unnecessary information like "I have used MS Excel to draw graphs." Irrelevant and inappropriate material is superfluous. Foreign terminology and phrases are not apropos. One should never take a broad view. Analogy is like feathers on a snake. Use words properly, regardless of how others use them. Remove quotations. Puns are for kids, not grunt readers. Never oversimplify: When adding material to your research paper, never go for oversimplification; this will definitely irritate the evaluator. Be specific. Never use rhythmic redundancies. Contractions shouldn't be used in a research paper. Comparisons are as terrible as clichés. Give up ampersands, abbreviations, and so on. Remove commas that are not necessary. Parenthetical words should be between brackets or commas. Understatement is always the best way to put forward earth-shaking thoughts. Give a detailed literary review.

22. Report concluded results: Use concluded results. From raw data, filter the results, and then conclude your studies based on measurements and observations taken. An appropriate number of decimal places should be used. Parenthetical remarks are prohibited here. Proofread carefully at the final stage. At the end, give an outline to your arguments. Spot perspectives of further study of the subject. Justify your conclusion at the bottom sufficiently, which will probably include examples.

23. Upon conclusion: Once you have concluded your research, the next most important step is to present your findings. Presentation is extremely important as it is the definite medium though which your research is going to be in print for the rest of the crowd. Care should be taken to categorize your thoughts well and present them in a logical and neat manner. A good quality research paper format is essential because it serves to highlight your research paper and bring to light all necessary aspects of your research.

Informal Guidelines of Research Paper Writing

Key points to remember:

- Submit all work in its final form.
- Write your paper in the form which is presented in the guidelines using the template.
- Please note the criteria peer reviewers will use for grading the final paper.

Final points:

One purpose of organizing a research paper is to let people interpret your efforts selectively. The journal requires the following sections, submitted in the order listed, with each section starting on a new page:

The introduction: This will be compiled from reference matter and reflect the design processes or outline of basis that directed you to make a study. As you carry out the process of study, the method and process section will be constructed like that. The results segment will show related statistics in nearly sequential order and direct reviewers to similar intellectual paths throughout the data that you gathered to carry out your study.

The discussion section:

This will provide understanding of the data and projections as to the implications of the results. The use of good quality references throughout the paper will give the effort trustworthiness by representing an alertness to prior workings.

Writing a research paper is not an easy job, no matter how trouble-free the actual research or concept. Practice, excellent preparation, and controlled record-keeping are the only means to make straightforward progression.

General style:

Specific editorial column necessities for compliance of a manuscript will always take over from directions in these general guidelines.

To make a paper clear: Adhere to recommended page limits.

Mistakes to avoid:

- Insertion of a title at the foot of a page with subsequent text on the next page.
- Separating a table, chart, or figure—confine each to a single page.
- Submitting a manuscript with pages out of sequence.
- In every section of your document, use standard writing style, including articles ("a" and "the").
- Keep paying attention to the topic of the paper.
- Use paragraphs to split each significant point (excluding the abstract).
- Align the primary line of each section.
- Present your points in sound order.
- Use present tense to report well-accepted matters.
- Use past tense to describe specific results.
- Do not use familiar wording; don't address the reviewer directly. Don't use slang or superlatives.
- Avoid use of extra pictures—include only those figures essential to presenting results.

Title page:

Choose a revealing title. It should be short and include the name(s) and address(es) of all authors. It should not have acronyms or abbreviations or exceed two printed lines.

Abstract: This summary should be two hundred words or less. It should clearly and briefly explain the key findings reported in the manuscript and must have precise statistics. It should not have acronyms or abbreviations. It should be logical in itself. Do not cite references at this point.

An abstract is a brief, distinct paragraph summary of finished work or work in development. In a minute or less, a reviewer can be taught the foundation behind the study, common approaches to the problem, relevant results, and significant conclusions or new questions.

Write your summary when your paper is completed because how can you write the summary of anything which is not yet written? Wealth of terminology is very essential in abstract. Use comprehensive sentences, and do not sacrifice readability for brevity; you can maintain it succinctly by phrasing sentences so that they provide more than a lone rationale. The author can at this moment go straight to shortening the outcome. Sum up the study with the subsequent elements in any summary. Try to limit the initial two items to no more than one line each.

Reason for writing the article—theory, overall issue, purpose.

- Fundamental goal.
- To-the-point depiction of the research.
- Consequences, including definite statistics—if the consequences are quantitative in nature, account for this; results of any numerical analysis should be reported. Significant conclusions or questions that emerge from the research.

Approach:

  - Single section and succinct.
  - An outline of the job done is always written in past tense.
  - Concentrate on shortening results—limit background information to a verdict or two.
  - Exact spelling, clarity of sentences and phrases, and appropriate reporting of quantities (proper units, important statistics) are just as significant in an abstract as they are anywhere else.

Introduction:

The introduction should "introduce" the manuscript. The reviewer should be presented with sufficient background information to be capable of comprehending and calculating the purpose of your study without having to refer to other works. The basis for the study should be offered. Give the most important references, but avoid making a comprehensive appraisal of the topic. Describe the problem visibly. If the problem is not acknowledged in a logical, reasonable way, the reviewer will give no attention to your results. Speak in common terms about techniques used to explain the problem, if needed, but do not present any particulars about the protocols here.

The following approach can create a valuable beginning:

- Explain the value (significance) of the study.
- Defend the model—why did you employ this particular system or method? What is its compensation? Remark upon its appropriateness from an abstract point of view as well as pointing out sensible reasons for using it.
- Present a justification. State your particular theory(-ies) or aim(s), and describe the logic that led you to choose them.
- Briefly explain the study's tentative purpose and how it meets the declared objectives.

Approach:

Use past tense except for when referring to recognized facts. After all, the manuscript will be submitted after the entire job is done. Sort out your thoughts; manufacture one key point for every section. If you make the four points listed above, you will need at least four paragraphs. Present surrounding information only when it is necessary to support a situation. The reviewer does not desire to read everything you know about a topic. Shape the theory specifically—do not take a broad view.

As always, give awareness to spelling, simplicity, and correctness of sentences and phrases.

Procedures (methods and materials):

This part is supposed to be the easiest to carve if you have good skills. A soundly written procedures segment allows a capable scientist to replicate your results. Present precise information about your supplies. The suppliers and clarity of reagents can be helpful bits of information. Present methods in sequential order, but linked methodologies can be grouped as a segment. Be concise when relating the protocols. Attempt to give the least amount of information that would permit another capable scientist to replicate your outcome, but be cautious that vital information is integrated. The use of subheadings is suggested and ought to be synchronized with the results section.

When a technique is used that has been well-described in another section, mention the specific item describing the way, but draw the basic principle while stating the situation. The purpose is to show all particular resources and broad procedures so that another person may use some or all of the methods in one more study or referee the scientific value of your work. It is not to be a step-by-step report of the whole thing you did, nor is a methods section a set of orders.

Materials:

Materials may be reported in part of a section or else they may be recognized along with your measures.

Methods:

- Report the method and not the particulars of each process that engaged the same methodology.
- Describe the method entirely.
- To be succinct, present methods under headings dedicated to specific dealings or groups of measures.
- Simplify—detail how procedures were completed, not how they were performed on a particular day.
- If well-known procedures were used, account for the procedure by name, possibly with a reference, and that's all.

Approach:

It is embarrassing to use vigorous voice when documenting methods without using first person, which would focus the reviewer's interest on the researcher rather than the job. As a result, when writing up the methods, most authors use third person passive voice.

Use standard style in this and every other part of the paper—avoid familiar lists, and use full sentences.

What to keep away from:

- Resources and methods are not a set of information.
- Skip all descriptive information and surroundings—save it for the argument.
- Leave out information that is immaterial to a third party.

Results:

The principle of a results segment is to present and demonstrate your conclusion. Create this part as entirely objective details of the outcome, and save all understanding for the discussion.

The page length of this segment is set by the sum and types of data to be reported. Use statistics and tables, if suitable, to present consequences most efficiently.

You must clearly differentiate material which would usually be incorporated in a study editorial from any unprocessed data or additional appendix matter that would not be available. In fact, such matters should not be submitted at all except if requested by the instructor.

Content:

- Sum up your conclusions in text and demonstrate them, if suitable, with figures and tables.
- In the manuscript, explain each of your consequences, and point the reader to remarks that are most appropriate.
- Present a background, such as by describing the question that was addressed by creation of an exacting study.
- Explain results of control experiments and give remarks that are not accessible in a prescribed figure or table, if appropriate.
- Examine your data, then prepare the analyzed (transformed) data in the form of a figure (graph), table, or manuscript.

What to stay away from:

- Do not discuss or infer your outcome, report surrounding information, or try to explain anything.
- Do not include raw data or intermediate calculations in a research manuscript.
- Do not present similar data more than once.
- A manuscript should complement any figures or tables, not duplicate information.
- Never confuse figures with tables—there is a difference.

Approach:

As always, use past tense when you submit your results, and put the whole thing in a reasonable order.

Put figures and tables, appropriately numbered, in order at the end of the report.

If you desire, you may place your figures and tables properly within the text of your results section.

Figures and tables:

If you put figures and tables at the end of some details, make certain that they are visibly distinguished from any attached appendix materials, such as raw facts. Whatever the position, each table must be titled, numbered one after the other, and include a heading. All figures and tables must be divided from the text.

Discussion:

The discussion is expected to be the trickiest segment to write. A lot of papers submitted to the journal are discarded based on problems with the discussion. There is no rule for how long an argument should be.

Position your understanding of the outcome visibly to lead the reviewer through your conclusions, and then finish the paper with a summing up of the implications of the study. The purpose here is to offer an understanding of your results and support all of your conclusions, using facts from your research and generally accepted information, if suitable. The implication of results should be fully described.

Infer your data in the conversation in suitable depth. This means that when you clarify an observable fact, you must explain mechanisms that may account for the observation. If your results vary from your prospect, make clear why that may have happened. If your results agree, then explain the theory that the proof supported. It is never suitable to just state that the data approved the prospect, and let it drop at that. Make a decision as to whether each premise is supported or discarded or if you cannot make a conclusion with assurance. Do not just dismiss a study or part of a study as "uncertain."

Research papers are not acknowledged if the work is imperfect. Draw what conclusions you can based upon the results that you have, and take care of the study as a finished work.

- You may propose future guidelines, such as how an experiment might be personalized to accomplish a new idea.
- Give details of all of your remarks as much as possible, focusing on mechanisms.
- Make a decision as to whether the tentative design sufficiently addressed the theory and whether or not it was correctly restricted. Try to present substitute explanations if they are sensible alternatives.
- One piece of research will not counter an overall question, so maintain the large picture in mind. Where do you go next? The best studies unlock new avenues of study. What questions remain?
- Recommendations for detailed papers will offer supplementary suggestions.

Approach:

When you refer to information, differentiate data generated by your own studies from other available information. Present work done by specific persons (including you) in past tense.

Describe generally acknowledged facts and main beliefs in present tense.

The Administration Rules

Administration Rules to Be Strictly Followed before Submitting Your Research Paper to Global Journals Inc.

Please read the following rules and regulations carefully before submitting your research paper to Global Journals Inc. to avoid rejection.

Segment draft and final research paper: You have to strictly follow the template of a research paper, failing which your paper may get rejected. You are expected to write each part of the paper wholly on your own. The peer reviewers need to identify your own perspective of the concepts in your own terms. Please do not extract straight from any other source, and do not rephrase someone else's analysis. Do not allow anyone else to proofread your manuscript.

Written material: You may discuss this with your guides and key sources. Do not copy anyone else's paper, even if this is only imitation, otherwise it will be rejected on the grounds of plagiarism, which is illegal. Various methods to avoid plagiarism are strictly applied by us to every paper, and, if found guilty, you may be blacklisted, which could affect your career adversely. To guard yourself and others from possible illegal use, please do not permit anyone to use or even read your paper and file.

CRITERION FOR GRADING A RESEARCH PAPER (COMPILATION) BY GLOBAL JOURNALS

Please note that following table is only a Grading of "Paper Compilation" and not on "Performed/Stated Research" whose grading solely depends on Individual Assigned Peer Reviewer and Editorial Board Member. These can be available only on request and after decision of Paper. This report will be the property of Global Journals.

Topics	Grades		
	A-B	**C-D**	**E-F**
Abstract	Clear and concise with appropriate content, Correct format. 200 words or below	Unclear summary and no specific data, Incorrect form Above 200 words	No specific data with ambiguous information Above 250 words
Introduction	Containing all background details with clear goal and appropriate details, flow specification, no grammar and spelling mistake, well organized sentence and paragraph, reference cited	Unclear and confusing data, appropriate format, grammar and spelling errors with unorganized matter	Out of place depth and content, hazy format
Methods and Procedures	Clear and to the point with well arranged paragraph, precision and accuracy of facts and figures, well organized subheads	Difficult to comprehend with embarrassed text, too much explanation but completed	Incorrect and unorganized structure with hazy meaning
Result	Well organized, Clear and specific, Correct units with precision, correct data, well structuring of paragraph, no grammar and spelling mistake	Complete and embarrassed text, difficult to comprehend	Irregular format with wrong facts and figures
Discussion	Well organized, meaningful specification, sound conclusion, logical and concise explanation, highly structured paragraph reference cited	Wordy, unclear conclusion, spurious	Conclusion is not cited, unorganized, difficult to comprehend
References	Complete and correct format, well organized	Beside the point, Incomplete	Wrong format and structuring

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